MECHANICAL ENGINEERING

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

June 1928

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Mechanical Engineering

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DEPARTMENTAL

ADVERTISING

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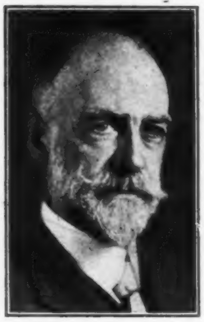
Crosby Field



W. F. Durand

Geo. A. Orrok

C. J. Freund

J. R. McCausland

Contributors to This Issue

W. F. Durand, author of the leading article in this issue on The Colorado River, is a scientist and consultant of international prominence in the field of mechanical engineering. While he has specialized largely in hydroelectric development, he has also taken an active part in the development of aeronautics and marine engineering. In 1918 and 1919 he was Scientific Attaché at the American Embassy in Paris and was a member of the Inter-Allied Committee on Inventions.

Since 1919 Dr. Durand has been a member of the Board of Consulting Engineers for the City of Los Angeles in connection with the development of hydroelectric power in that city along the line of the Los Angeles aqueduct. This work was in connection with their proposed participation in the Boulder Canyon project on the Colorado River.

Dr. Durand was a member of the President's Aircraft Board in 1925. He is a member of the National Advisory Committee for Aeronautics and the National Research Council. He is a past-president of The American Society of Mechanical Engineers, a life member and gold medalist of the American Society of Naval Engineers, a member of the National Academy of Sciences, a fellow of the American Academy of Arts and Sciences, and a member of the American Institute of Electrical Engineers, the Society of Naval Architects and Marine Engineers, and the Société Technique Maritime.

Geo. A. Orrok, consulting engineer, New York, N. Y., was graduated from Massachusetts Institute of Technology in 1888. From 1891 to 1898 he was associated with the late Dr. F. S. Pearson, engineer, and from then until 1916 was with the New York Edison Co. He is a member of many engineering societies, including The American Society of Mechanical Engineers, the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Naval Architects and Marine Engineers, the Institute of Consulting Engineers. The Franklin Institute, and the Institution of Mechanical Engineers (London).

Crosby Field is vice-president, secretary, and director of the Brillo Manufacturing Co., as well as vice-president and director of the Chemical Machinery Corporation and the Chemical Machinery Construction Co., Inc. He holds the degrees of B.S. from New York University, M.E. from Cornell University, and M.S. from Union University. From 1912 to 1914 he was associated with the General Electric Co., and during the following year was engaged in private consulting practice in New York City. From 1915 to 1917 he held the position of chief engineer of the Standard Aniline Products, Inc., resigning to enter the Ordnance Department of the U.S. Army. Upon his return to civil life he became engineering manager of the National Aniline & Chemical Co., Inc.

C. J. Freund was graduated from Campion College with an A.B. degree and entered the College of Engineering of Marquette University. His course was interrupted by service in the United States Army during the World War. After his discharge in 1918 as first lieutenant of infantry he returned to college and received an M.E. degree in 1922. He entered the employ of the Falk Corporation and was successively chain man, timekeeper, and heat pourer in the foundry. Later he became labor foreman in the yard and foundry. In 1924 he was assigned to the Apprentice Department, which was placed in his charge late in 1925.

J. R. McCausland is superintendent of the coal-bureau and steam-heating departments of the Philadelphia Electric Co. For the past twenty years, Mr. McCausland has been associated with the engineering department of this firm in construction and operating work, serving also during this time with the United States Engineers in France during the World War. He studied mechanical engineering at the Temple University in Philadelphia.

This Month's Cover shows a very beautiful view of Boulder Canyon in the Colorado River, one of the sites referred to in Dr. Durand's article in this issue.

COMING A.S.M.E. MEETINGS

There are many interesting meetings, dates of which are given below, scheduled for the next few months. Details are being published in the current issues of the A.S.M.E. NEWS.

National Oil and Gas Power Meeting, Pennsylvania State College, June 14 to 16.

National Aeronautic Meeting, Detroit, June 28 to 30.

National Fuels Meeting, Cleveland, September 17 to 20.

Summer Meeting, St. Paul-Minneapolis, August 27 to 30.

National Machine-Shop Meeting, Cincinnati, September 24.

New England Industries Meeting, Boston, October 1 to 3.

MECHANICAL ENGINEERING

Volume 50 June, 1928 No. 6

The Colorado River Problem

The River Itself—Flood and Silt Evils—Possible Water-Supply and Power Benefits from Boulder Canyon Project—Feasibility of All-American Canal—Capacity and Location of Reservoir—Economics of Project, Etc.

By W. F. Durand,[1] Stanford University, Calif.

THE subject of the Colorado River is in considerable degree controversial. My own contacts with the problem have not led me into particular consideration of these aspects, having more largely been concerned with a study of the physical conditions and of the economic problems. It is with regard to these conditions and problems that I shall speak. First I shall discuss briefly the Colorado River as a physical entity.

Courtesy Atchison, Topeka & Santa Fe Ry. Co.

Hermit's Rapids, Colorado River

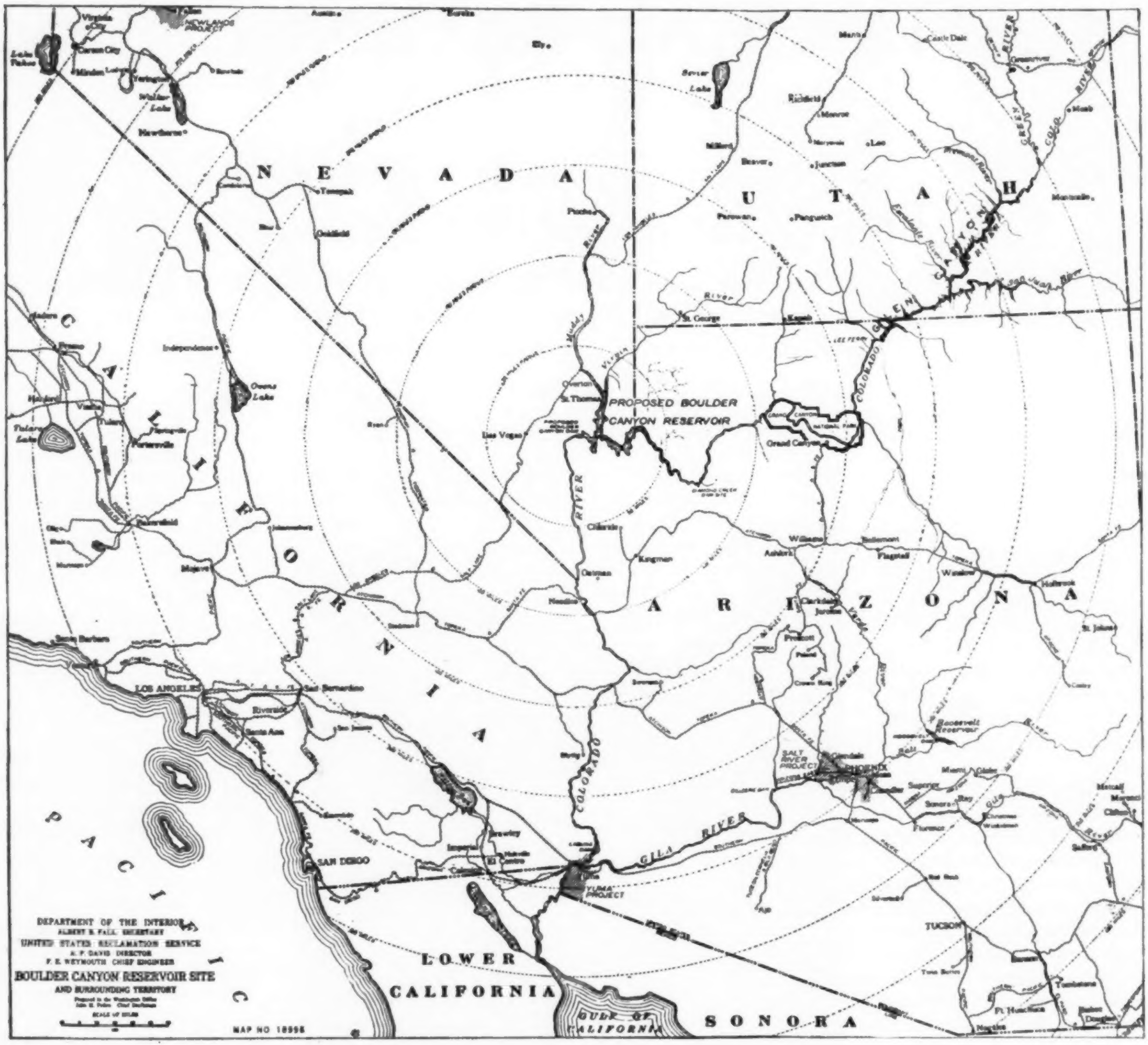
The Colorado River

Many of you here, perhaps all of you, have visited the Colorado River, but in order that we may all start square, I shall draw a very sketchy picture of the river. As we know, it flows through and between seven different states, it is 1750 miles long, from the junction of its longest tributary, the Green, down to its mouth where it empties into the Gulf of California. It drains a territory of 244,000 square miles, a territory which over a long period of years supplies on the average 21,000,000 acre-feet of water per year. Not all of this water, however, reaches the river. The amount that does reach it is, again on the average, some 4,000,000 acre-feet a year less, giving an average annual output of the river of about 17,000,000 acre-feet. There is, however, very wide fluctuation from year to year, measured over a long period of time. The total flow of the river may go as low as 10,000,000 or 12,000,000 acre-feet, and up to something like 26,000,000 acre-feet; that is, measured over a long period of time. Again with regard to the rate of flow, the average rate of flow is about 21,000 to 22,000 second-feet, taken over an average year or series of years, but subject to wide variations. The rate of flow may drop to as low as 5000 or 6000 second-feet, and under flood conditions go as high as 150,000 or 200,000 second-feet. It is recorded that in 1924 the flow fell to 1500 second-feet, and while I have mentioned a high figure of 200,000 second-feet, it is estimated that in 1884 the flow reached a figure of 384,000 second-feet, and there are certain marks along the lower river which indicate that at some interval of time the flow may have reached as high as 500,000 second-feet. So here we have a possible variation in flow which spans the range between 1500 second-feet and 500,000 second-feet.

But the river carries not alone water, it carries an enormous burden of silt as well. A year or so ago there seemed good reason to believe that the amount of silt carried by the river was of the order of 90,000 to 100,000 acre-feet in a year, this based on literally thousands of measurements taken near Yuma. The river was cross-sectioned, divided into stations, and sampling bottles used, all the operations being according to a prescribed method, with results as I have stated, indicating a movement of silt of the order of 90,000 to 100,000 acre-feet per year. This of course took into account only the silt held in suspension by the water and not the bed silt or silt rolled along the floor of the river, much as the sand in sand dunes is rolled along by the wind. It is recognized that there undoubtedly is a certain amount of this bed silt. At a later date, about 200 miles above Yuma, the Agricultural Department made tests in the same general way under the same conditions and by the same methods, and when these results were averaged and compared there was found a distinct difference between them and the tests made near Yuma. In the total average taken at Topock the silt burden ran of the order of 130,000 to 140,000 acre-feet per year, easily 50 per cent more than indicated by the tests made at Yuma. The question

[1] Emeritus Professor of Mechanical Engineering, Stanford University. Past-President A.S.M.E.

Address at a meeting of the San Francisco Section of the A.S.M.E., San Francisco, Calif., January 26, 1928.



Boulder Canyon Reservoir Site and Surrounding Territory
(Dotted circles showing distances from dam site increase in radius by 50-mile steps from center.)

of the wide variation was an interesting one, one to which I have given considerable thought and which I have discussed with engineers of the Department of Agriculture. And about the most reasonable answer to the question seems to lie in the fact that the gradient of the river is definitely steeper at or near Topock than it is near Yuma; and because of this fact, possibly all or substantially all of the silt at or near Topock is in suspension, giving a higher amount of silt to the bottle sample than was obtained near Yuma where the gradient of the river is flatter and part of the silt is carried along the floor of the river. In any event, whether or not that is the explanation, the fact of the difference remains.

The burden of silt thus carried by the river is enormous in magnitude, and its deposition in the lower reaches of the river gives rise to some of the most serious problems which the control and regulation of the river involve.

We have thus the Colorado as a physical entity, this river with its wide variation in rate of flow, varying with the different months of the year and from year to year and bearing not only water but this burden of silt as well. As to what this silt is, I will take a moment to speak of that. I have gathered and examined a good many samples. The silt is composed of finely ground particles of quartz, some of them about one-ten-thousandth of an inch in diameter, the larger portion of the finer silt running between 0.0001 and 0.001 in. in size.

Flood and Silt Evils

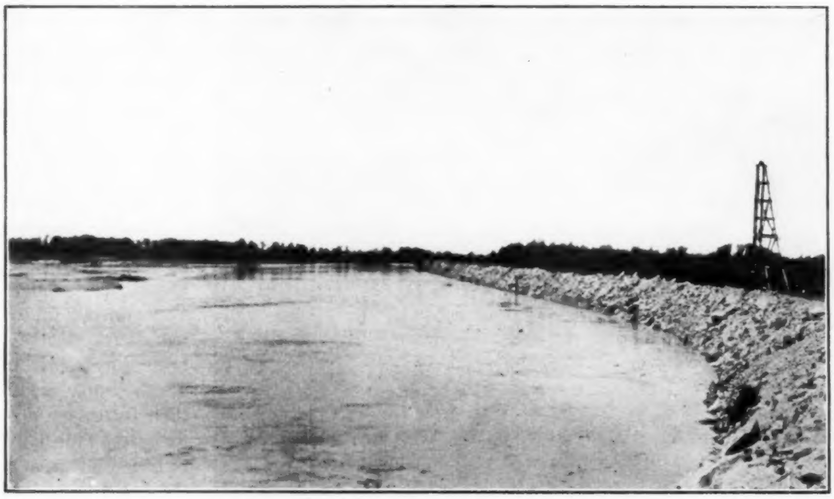
Going on now from the matter of physical characteristics, let us see what some of the consequences are. In the first place, as to the silt. The gradient of the river from the Mexican border to the Gulf is slight, consequently the silt is dropped practically to the bed of the river and keeps building up that bed. The same conditions obtain, of course, on the Nile and on our own Mississippi. The consequence is that the whole delta cone in lower California has been gradually built up, until much of the land lying along the river is definitely below the level of the river itself. Furthermore, as is well known, the Imperial Valley, lying to the north, partly in Mexico, more largely in California,

is distinctly below sea level. As a matter of fact it is part of the old sea bed, some of it 250 ft. below the level of the sea. Along the lower river the level of the water is 30 or 40 ft. above the level of the sea, and it thus results that much of the valley is from 150 to 200 ft. or more below the level of the water in the river. It is obvious, therefore, that as result of an unusual flood and a topping of the banks there would be this definite gradient inviting a flow of the river toward and into the valley, carrying destruction in its wake. You will remember that this is just what happened in 1905, and many millions of dollars were spent before the river was brought back under control. In an attempt to control the river, heavy rock embankments or levees have been built and are maintained by the irrigation company; but as the bed of the river rises, these embankments have to be raised as well. As a result of the silt cone thus formed at a point perhaps half-way between where the river leaves the United States and where it reaches the Gulf, there is no river at all. It simply disappears in a great jungle or morass of semitropical undergrowth, finally to be recollected on the other side of this delta cone, and ultimately finds its way to the Gulf in its regular channel. It cannot be otherwise as long as the silt is carried by the river and as long as there is that reduction of gradient through lower California. So that, as a result of the silt burden thus brought down and deposited along these lower reaches of the river, taken in combination with the extreme variation in flow, we have the possibility of the overtopping of the banks of the river. Overtopping, however, is not the only or perhaps the most serious danger. In fact, the people charged with the responsibility of controlling the river as best they may, are perhaps still more afraid of undercutting. As in the case of all such meandering streams, the river, in changing direction, or as the result of conditions along the banks, develops whirlpools and boils. These may literally bore down into the bed of the river, even under the stone levees, and presently a section will drop down, leaving the river free to flow through the breach thus formed. Sometimes a second line of defense has been erected by way of a second embankment, so that if the river gets by the first embankment the second one is counted on to hold it in check. There are then these ways in which the river may give trouble, either by overtopping or by undercutting. It is very sure that next May or June, should there be more than ordinary flood conditions in the Colorado, the banks would risk overtopping. Any condition such as developed in the Mississippi Valley last year would result without doubt in the overtopping of the banks by the river and in damage which no one can estimate.

There is then this definite consequence, this measure of potential trouble for the Imperial Valley; and not alone for the Imperial Valley. There is also a large acreage in Arizona, in the Yuma and Parker districts and in other considerable tracts along the river, some of them prosperous and under good headway. They are subject to the same hazards. True, they are not as large as the Imperial Valley, but to the people who live there the personal interest and potential hazards are just as great.

In addition to the element of hazard due to flood conditions, there is also the problem of the carrying of the silt on to the land. There are two types of consequences involved, one of expense and the other involving the impairment of the agricultural value of the land itself.

First, as to the expense. The coarser particles of silt are in large part dropped out at the point of diversion, but the finer portions flow on with the water and are in part deposited in the canals and in part reach the land itself. The silt deposited in the canals must be disposed of by the canal company. You will notice unusually high banks along the canals. These are simply the silt which has been dredged out and piled along the banks. It costs the canal company about one dollar per acre per year just to dredge out the canal silt, and that cost has to be carried on and paid by the irrigators. When the silt gets on to the land of an irrigator it tends to build up a form of delta cone and must be taken care of by spreading out over the land. This requires an expenditure of about $2 per acre per year. Thus about three dollars per acre per year, or about one and one-half millions of dollars for the district, is the cost for handling this situation. So much for the element of expense.



Lower River Showing Levee with Rock Facing

The other feature is this: The silt which goes on to the land is an upper cut, very fine, finer than the average silt; the consequence is that these fine particles infiltrate into the general soil of the locality, choke it up, and make the soil less pervious and in some cases practically impervious. A farmer may turn the water down a furrow between rows of lettuce or other garden product. For a time the water sinks readily into the soil. Then the deposited silt begins to form a fine coating, an impervious blanket, as it were, holding the water in the furrow without further penetration into the soil. The only remedy will be to go into the furrows again with a plow or in some way to break up the impervious blanket of silt which has been laid down. I have talked with engineers of the Agricultural Department because they are interested in the silt from this standpoint, and they confess to a serious apprehension with regard to the future of the land unless something is done to prevent this sealing up of the soil by the silt. These are two of the specific results which come from the silt and which, of course, must be corrected if the people are to continue on that land.

Water Supply for the Imperial Valley

That is not all, however. In order to get water on to the land in the Imperial Valley, on American soil, it was necessary to divert the water on American soil just above the international boundary and to carry it across, into, and through Mexican terri-

tory for fifty or sixty miles before bringing it back into the Imperial Valley in California. The agreement entered into at that time provided that the Mexican irrigators might take one-half of the water carried by the canal. There has been, however, some difference of opinion as to whether this might mean one-half the flow at any one time or one-half the total flow for the year taken at such times and at such rates as their conditions might require. Under normal conditions of flow, no trouble is likely to arise under either interpretation. But at times of very scanty flow, with the irrigators on the Mexican side inclined to insist upon their right to take such water as was needed so long as the total amount taken for the year did not exceed their due proportion, serious trouble might result for the Imperial Valley. There was exactly such a condition in 1924. There was not enough water flowing to take care of the needs on both sides of the boundary. The irrigators of Mexico were inclined to take what they needed, and there resulted for a time a serious condition of water shortage in the Imperial Valley. I think that none of us would feel very happy if the water upon which we depended for life itself had to come 60 miles through foreign territory before we could dip our cups into it. So much for the conditions of evil. What about the other side of the shield?

LOWER-RIVER SILT BANKS AS FIRST STEP IN FORMING A SECOND-LINE LEVEE

Possible Benefits by Way of Water for Irrigation and for Municipal and Domestic Use

If there are disadvantages, there are also advantages. In the first place, the river carries water—that, of course, is the great thing. In arid countries water spells life. The river carries water, and there are large areas of land, suitable for irrigation, waiting only for the water to be supplied. There are now in that portion of the country, particularly in Arizona and California, about 500,000 acres of class A agricultural projects waiting development by way of irrigation. A class A project is one about which there is no substantial doubt. There is in addition about as much area in class B and C projects, representing land less easy to bring under irrigation but undoubtedly due ultimately to contribute its share to our agricultural wealth. In any event there are at present about half a million acres of land waiting to be developed when water for irrigation is provided.

Again, people in southern California are becoming anxious about the future supply of drinking water. The condition is really serious with reference to several communities, and the people in that part of the state are definitely satisfied in their own minds that if they are to go on and develop, to continue to grow industrially and prosper, they must have more water. But a large source of water supply is not built over night. It requires long preparation and study, in advance of a still longer time for the actual construction. The city of Los Angeles, for example, believes that within a period of eight to ten years it will have lived up to its present source of supply, and under these conditions it certainly is high time for them to take under active consideration the source of their next and larger supply. But it is not alone the city of Los Angeles. The entire territory in southern California is interested in this problem. As this territory has become more and more settled up, with larger and larger demands on the local groundwater for irrigation and for municipal use, the level of underground water has continually lowered and the limitation of the supply is very clearly in sight. These communities, therefore, are looking to the Colorado River as the only adequate source for their future supply with special reference to municipal and domestic purposes.

Possible Benefits by Way of Power

Again, water is not the only good thing which may be derived from the river. If we can combine water with suitable topography, we may extract power, and the water will be still just as wet and just as suitable for drinking or for irrigation as before. This part of the state of California, as you know, has been developing very rapidly in recent years. The demands for electric light and power have been increasing by leaps and bounds. These people are therefore anxious about their future supply of power. They look forward, especially in certain districts, to becoming great centers of industry, and they feel that one important factor in such upbuilding is cheap power.

We have thus as potential benefits from the Colorado River, water for irrigation, water for municipal purposes, and hydroelectric power. To realize these benefits, however, certain engineering conditions must be fulfilled. What are these?

Conditions for Suppression of Evils and for Realization of Benefits

In the first place, if water is to be utilized for municipal purposes and for irrigation, measures must be taken to prevent the waste of the water when the flow is larger than the rate of current use. Water that cannot be thus used must be made available for later use by storage. Obviously, then, the first condition is to provide means for storage; and if means are provided for adequate storage with proper regulation of flow at the dam, we shall have the river under control. The first condition is therefore that we have the river under control instead of allowing it to flow uncontrolled as at the present time. In connection with the control of the river and the storage of flood waters, we must also catch and store the silt and prevent it from going down the river. However, the storage of water and the trapping and storage of silt would not fully solve the problems of the Imperial Valley with their present water supply coming to them through some sixty miles of foreign territory. They feel, and not unnaturally, that in devoting their lives to the cultivation of the Imperial Valley, they should have some better measure of protection against unusual conditions than that furnished by a water supply coming to them through some sixty miles of foreign territory. In order to meet this phase of the situation,

the general project includes the so-called "All-American Canal," a waterway which would get its water from the Laguna Dam, some miles above the present point of diversion for the Imperial Valley and which now supplies the Yuma territory. It would then run across the country, all the way in American territory, and deliver its water for the Imperial Valley into the present distributing system. But if such a project is considered at the present time, why was it not carried out in the beginning? That is too long a subject to consider here in detail, but it may be sufficient to say that due to the topography the undertaking was too difficult and too expensive to be carried out under the conditions which prevailed when the water was first brought into the Imperial Valley. The present project thus contemplates a dam, a reservoir, and an all-American canal.

Capacity of Reservoir Required

Passing on to some questions of detail, the first is, How much storage will be required? Here I must leave the field of basic facts and in a sense enter the field of opinion. The reservoir must include a pocket for the silt. This material must be prevented from passing on to the lower reaches of the river. Again there must be flood storage in order that the discharge under flood conditions of the river may be reduced to any specific or desired figure considered safe for the conditions along the lower river, and finally there must be provisions for storage which from season to season will take care of long-period fluctuations. This is all the more important by reason of the seven-states compact between the states which are interested in the Colorado River. The seven-states compact provides that 15,000,000 acre-feet per year shall be divided 50-50, 7,500,000 to the upper-basin states and 7,500,000 to the lower states; but the upper-basin states are not obligated to deliver 7,500,000 acre-feet in any one year. They must deliver 75,000,000 acre-feet over a ten-year period, but without specification as to the amount in any one year. This means that they may deliver in such quantities or at such rate as they see fit, provided the full amount is delivered over the ten-year period.

Now of these three kinds of storage, how much, first, for the silt? It would seem reasonable that any capacity for storage should provide for at least the bond period, and longer if possible. This would mean that a provision for forty or fifty years should be the minimum, with a larger capacity very much to be desired. If the annual burden of silt is taken at something like 130,000 acre-feet, this would mean a minimum capacity of about 6,500,000 acre-feet, with a preferable capacity of perhaps 7,000,000 to 8,000,000 acre-feet.

Then how much for flood protection? What is a safe maximum flow to allow to go down the river? There is here a difference of opinion. I have been down the length of the river as far as there is a river, and have had that much opportunity of studying its conditions. I base my opinion, however, rather on discussions with the people who have been working there for twenty years; and in their opinion it would be highly desirable to reduce the flow to 40,000 or 50,000 second-feet. Below 40,000 second-feet they are not worried, they can take care of it; but when the flow goes up to 50,000 or 60,000 second-feet, it begins to develop whirls and boils with danger of undercutting. And then, of course, if it went on to some extreme flow, there would be the danger of overtopping. If we accept the general estimate of the people who know most about it from actual contact, the flow should be controlled to 40,000 to 50,000 second-feet, and it becomes a mere matter of arithmetic as to how much should be the storage capacity to take care of flood conditions, having in mind a flood with maximum flow of perhaps 200,000 second-feet; or in other words, such a flood as may be anticipated at almost any time. It is easily shown that for such a flood a storage of 7,000,000 or 8,000,000 acre-feet would be required in order to reduce the maximum flow to about 40,000 second-feet over the flood period. If floods of a larger maximum flow, such as may occur at long intervals of time, are to be provided for, then naturally an increasing amount of flood storage, up to 12,000,000 or 14,000,000 acre-feet, would be necessary. In any event it would seem that in order to have any reasonable margin with reference to flood conditions, there should be a storage capacity of at least 8,000,000 acre-feet.

Brush Mats Used in Forming Temporary Low-Water Diversion Dam for Water Used in Imperial Valley

Again, how much will be required for the long seasonal variations? The answer here is again somewhat a matter of opinion but a reasonable estimate seems to place the figure at some 10,000,000 to 12,000,000 acre-feet, or more if feasible. If these various requirements are added together we shall arrive at a result of something like 25,000,000 or 26,000,000 acre-feet. If then we could find a place where a dam could be constructed, giving a reservoir with a capacity of, say, 26,000,000 acre-feet, it would meet all of the conditions I have indicated so far as regulation is concerned. It would provide for the regulated flow of the river, and it would control or store the silt. In order now to meet the power requirements, the topography must be suitable; we must find a place where we can let the water down from a high level to a lower one. Before discussing this matter in detail, however, let us consider briefly certain matters relating to the all-American canal.

Feasibility of All-American Canal

There have been questions raised with regard to the practicability of this project—whether it could be dug as a ditch. I am convinced that the ditch can be dug, and that when once dug it can be made to operate effectively. In digging the ditch, it will be necessary to go through a range of sand dunes covering a distance of 10 or 12 miles overlying a mesa formation and with maximum depths of 100 to 150 ft. No doubt the problem of excavating through these sand dunes is one of some difficulty,

but it certainly can be done. It has again been said that even if the ditch is dug, the winds will fill it up with blow sand and render its operation ineffective. Careful measurements made on the spot by a skilled observer and covering a considerable period of time indicate that the amount of sand which would enter the section of a canal is very much less than might be anticipated, so small indeed as to represent a quantity far below the amount which, as silt, could be readily carried along by the water in the canal with the velocity anticipated.

Very similar conditions exist at the Suez Canal, and it was predicted before the opening of this canal that trouble from blow sand would result. These predictions, however, have never been realized, and there has never been experienced any trouble whatever in keeping the canal open so far as the blow sand is concerned. Also there are various ways in which such conditions may be controlled, at least to a degree. There is a grass down there which sends out long roots and which with a little irrigation could probably be made to form a protective barrier; or again low shrubbery might be planted and used for that purpose.

Location of Dam and Reservoir

However, leaving that question of the all-American canal, let us turn to the place where we can find room for 26,000,000 acre-feet of storage. If we look up and down the river between Lee's Ferry and Yuma, there is just one place and only one where all of the conditions can be met, and that is in the general vicinity of Boulder Canyon. Some of you may have been confused about the terminology of Boulder Canyon and Black Canyon. They are two different locations and are about 18 miles apart. The general locality is down near the point of Nevada, where the river turns south, forming the boundary between Arizona and Nevada. The Boulder Canyon or upper site was the first to be examined, and that gave the name to the project. Later on, investigation was made of the lower or Black Canyon site, and certain advantages, partly geographical, partly engineering and economic, were found to turn the scale on the whole in favor of the lower site. It appeared, however, inadvisable to attempt to change the name of the project, so that the old name of Boulder Canyon has been allowed to remain while the actual site is at Black Canyon. There is here an admirable site for the dam from an engineering viewpoint, with a reservoir having a storage capacity of about 26,000,000 acre-feet. This would require a dam 550 ft. high, carrying the surface of the water up the river to another good site for a power dam at Bridge Canyon. Ultimately a power dam of about the same height as at Black Canyon should presumably be built here, carrying the surface of the water back to the lower limits of the Grand Canyon National Park. Two such dams with some ten feet margin between the upper level of the Black Canyon dam and the tailwater of the Bridge Canyon dam would then utilize this whole stretch of river between the limits of the Grand Canyon National Park and Black Canyon. With a dam at Black Canyon 550 ft. high and with the conditions of the river as contemplated, there will be a mean power head of some 400 to 450 ft., which, with the amount of water flowing, will provide abundantly for the continuous development of 550,000 hp. The load factor contemplated is about 55 per cent, and this would imply an installed capacity of about 1,000,000 hp. With the continuous flow of the river at a later time with large amounts of water used in the upper basin for irrigation, but with a series of reservoirs along the river providing increased storage and the reduced fluctuation of water level required at Black Canyon, there should still be sufficient water for the continued development of the 550,000 hp. contemplated. Ultimately it may be anticipated that the Black Canyon dam would be used at nearly its maximum head, thus reducing the amount required for the specified power. In any event, over a long period of years, presumably far outrunning the bond period, the conditions here should apparently insure the reliable development of such an amount of power.

What, then, can be done with this development? Is it feasible? Can it be built as a physical undertaking? Is it economical? Is it justified? Of the thousands of things we may do, only those are justified which meet economic conditions. If it is feasible, is it economically sound? There is undoubtedly ground for difference of opinion here. I believe it is only fair to say, however, that the larger opinion is that the dam is feasible and the project is economically sound. The project is one involving some hazard, but it is composed of elements which are in themselves similar to undertakings which are being done every day by engineers. The basic problems are the same. The scale on which some of them must be carried out is somewhat beyond existing precedent.

Economics of the Project

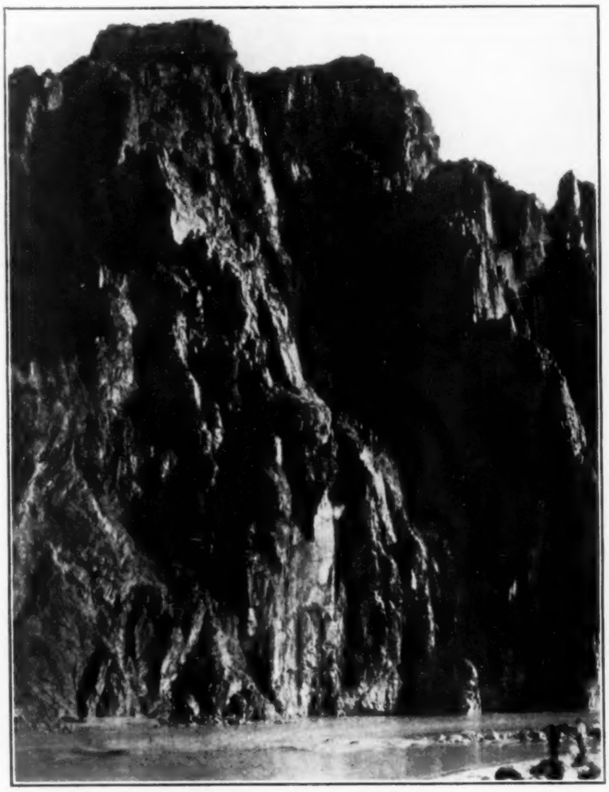
With regard to the estimates of cost, it is estimated that the dam will cost $41,500,000, the power plant $31,500,000, and the canal $31,000,000, with interest during construction of $21,000,000. With regard to the adequacy of these figures, or estimates, there is ground for difference of opinion. I have gone over them with a good deal of care, and I am inclined to believe they are conservative and safe. I believe that modern conditions will enable us to reduce the figure given for construction of the canal. There is very little margin of uncertainty in the construction of the power house, and, as I have said, the figures for the dam appear to be conservative. With regard to the $31,000,000 for constructing the canal, the estimate was made at the close of the war when prices were at their peak. Costs are lower at the present time, and in the domain of machinery for moving such material, great strides have been made, and by applying current prices and modern equipment I believe a definite saving can be made in the estimate of $31,000,000. Estimates have been made as low as $20,000,000, and in any case it seems reasonable to anticipate a definite reduction in the $31,000,000 estimate. Taking the total cost of the project at $125,000,000, the interest charge of $21,000,000 is again too high. Not all of the construction is going to take ten years. The dam might, but the canal should be completed in four or five years, depending on at how many points the project is attacked. A project like the dam can only be made the subject of attack at the two ends, but an undertaking like the canal can be attacked at as many points as the economics of the equipment used will permit, and estimates made from this viewpoint indicate a period of four or five years.

Setting aside, however, the possibility of lowering the estimates of cost and accepting $125,000,000, what will be the basis for financing? First, the interest must be paid, then cost of operation and maintenance and retirement of the bonds must be provided for. With assumed conditions, this is a simple problem in accounting. In the particular set-up which I had the honor of presenting to the Secretary of the Interior I suggested setting aside no money for retirement of bonds during the first ten years, and then in the period of 30 to 40 years following the ten-year period, suitable amounts for redemption should be set aside. What are, then, the sources of revenue to meet such a program of payments? They are water and power. Water is going to be used in increasing quantities, but the irrigators of the Imperial Valley can hardly be expected to pay for the water as such. Under present agricultural conditions that is a burden which the irrigators would find it difficult to carry. It will not, however, be unreasonable to expect that they can afford to pay something for the operation of the canal by reason of the reduced cost of expense in caring for the silt. The silt problem, of course,

will not be entirely eliminated from the Imperial Valley. There will probably be such a problem for some years, gradually decreasing in importance. Again, there will be a saving due to reduction in the cost of maintaining levees and embankments. Again, there is water sold to communities for municipal and domestic use. It appears that there may properly be expected a revenue of $1,000,000 to $1,500,000 under the head of water.

The remainder of the revenue must obviously come from the power, something over 3,000,000,000 kw-hr. Under the conditions assumed the numerical result is readily reached, and it indicates a possible selling price for the power delivered at the switchboard in the power house very close to 0.2 cent per kw-hr. If then a price of 0.2 cent or anything larger could be assured, the project would seem to have a reasonably secure economic foundation. But there is no market for the power at the dam itself, and in order to sell the power at any such figure at the dam it must appear that the cost of such power, when carried to localities where there is a market and when made equally reliable with local power developed at such point, can be made at a figure which will insure its sale in competition with power from other or local sources.

Again, there is the question as to whether there is the capacity within reasonable transmission distance of Boulder Canyon for absorbing any such amount of power. With regard to this latter point, the most careful estimates indicate that beginning with the delivery of some power with the project partly completed, the entire output of the project should be absorbed by the growing market in the territory within, say, 300 miles of the dam, and within a period of two or perhaps three years subsequent to the completion of the project.



CLIFFS OF THE COLORADO

It may therefore be assumed that there will be a market for such amounts of power, provided it can be delivered at market points at a price showing some margin of advantage in comparison with power from other sources.

Allowing about 12 per cent loss in transmission and taking 0.15 cent as the cost of transmission for a kilowatt-hour delivered, we have with any assumed cost at the Canyon, the ultimate cost of a kilowatt-hour laid down in southern California or at any other distant market point. We then have to consider its desirability from the standpoint of reliability. There are two types of unreliability—water supply and transmission hazard. I do not consider that the water hazard is of importance—there will be a large excess of water for from 25 to 50 years, but you cannot get away from the transmission hazard over 300 miles of line. Therefore in order to give the customer a guarantee of reliable delivery, it would be necessary to back up Colorado River power with a small amount of steam power. As to how much of a steam plant should be provided, there may be a question of opinion. However, what seems like a reasonable estimate indicates a resultant additional cost of such combined power of some six- to eight-hundredths of a cent. This would then give the aggregate resultant cost of Boulder Canyon power delivered at a market point and made equal in reliability with power, for example, from local steam sources. What, then, is the margin of cost between Boulder Canyon power and steam power not only under present conditions, but what will it be under conditions that will prevail 30 or 40 years hence? There are two tendencies to be considered, that of the cost of fuel and the trend of improvement in thermal and station efficiency. The actual fuel cost at the present time is something less than half of the cost at the switchboard. Considerations based on the principles of thermodynamics and taking into account the efficiency of our most improved modern steam stations, seem to indicate a limit in the ultimate improvement to be anticipated at something like one-third of the present fuel cost. If the fuel cost is less than half of the switchboard cost, it would not then appear probable that improvements in thermal and station efficiencies as such would be able to reduce the cost by more than one-sixth of the present figure. However, such saving must probably be discounted to some extent by reason of the increased cost of equipment to be anticipated with greater refinements in operation and the resulting increase in fixed charges on such equipment.

On the other hand, with regard to fuel, the price of oil is now about $1 per barrel, although on certain present contracts the price is understood to be 80 to 85 cents per barrel. However, no fuel at the present time can be bought for any such price and no long-time contracts can be made even at a price of $1 per barrel. The general trend in the price of oil has been upward. Oil, as we know, is limited in quantity, and it is difficult to foresee what the price will be over a period of 40 years. We shall probably have to give up oil altogether and go to coal, but whether from oil or coal the fuel cost of power from steam is going to increase with the cost of fuel, and on the whole I am inclined to look for an overall increase in the cost of power as the years go by rather than a decrease or a stationary figure. An increase in the cost of oil per barrel of some 40 or 50 cents would probably wipe out all of the advantage due to improvement in thermal and station efficiency which we can reasonably anticipate. In any event, at the present time with oil at $1 per barrel, with Boulder Canyon power backed up with a fair margin of steam power and with a cost of 0.3 cent per kw-hr. at the Canyon, there would be no margin of advantage whatever, and there would be no inducement in looking to Boulder Canyon for power and it may be questioned whether a ready market under these conditions could be found. If, however, the cost of the power at the Canyon can be made 0.25 cent, there begins to appear a small margin in favor of the Canyon power. With a price at the

Canyon of 0.225 cent the margin is unquestioned and definite, and with a price of 0.20 cent, as appears quite possible from the economic set-up, the margin is something of the order of 1 mill or perhaps a trifle more. Obviously, if power sold outside the state of Arizona is subject to something equivalent to an export tax, the margin of advantage would be correspondingly reduced. It is obvious, furthermore, that even in the case of such a tax or its equivalent, it could not absorb the entire margin of advantage for the Canyon power. Otherwise the inducement for going to such source for power would be lacking. There must obviously be a definite even if a small advantage reasonably well assured for the Canyon power in order to insure a reliable and continuous market.

Other Proposals

There is but scant time to give even the briefest notice of certain other propositions which have been made at one time or another

Black Canyon Dam Site

regarding the control and regulation of the Colorado River and the solving of the problems previously indicated. A dam and reservoir have been proposed at Glen Canyon just above Lee's Ferry. A reservoir at this side would be less advantageous than at Boulder Canyon for the following reasons:

The geographical formation is such that, in the opinion of experts who have examined the site, it would not be wise to attempt a dam higher than about 400 ft. The dam would be larger relative to height, and correspondingly more expensive. The resultant storage would cost two and one-half to three times as much per unit as at Boulder Canyon. The reservoir would not control certain important tributaries of the river, either with reference to floods or silt. The site is some 360 miles farther from the lands to be irrigated than is Boulder Canyon, with correspondingly greater difficulty of control relative to irrigation. The site is relatively inaccessible, and there are no local materials suitable for the construction of the dam. Finally, the location is so far from markets for power as to be economically out of the question so far as a self-sustaining enterprise is concerned. Nevertheless the site is a valuable one with reference to the ultimate development and control of the river, and at a later time presumably a dam should be erected at this point, thus providing for some portion of the required storage capacity for water and silt and increasing in corresponding degree the value of all projects lower on the river.

For purposes of flood control only, a dam and reservoir have been proposed at or near Topock, just below the Needles. At this point a dam of 180 or 200 ft. might be built with a storage capacity of some 10 or 12 million acre-feet. Such a project would for the time being provide flood control, but would meet no other of the various requirements. Its useful capacity would be rapidly impaired by the accumulation of silt, it would not provide for long seasonal regulation, and as a power site it has no significance whatever.

On the whole, it seems fair to conclude that the proposed project at Boulder Canyon meets the various requirements in a higher degree than any other site or combination of sites along the river, and that it is the only site which does represent at the same time an economically feasible solution of the various problems above outlined.

Discussion

J. D. Galloway.[2] It would be of interest to have Dr. Durand's opinion on the amount of silt at present in the river bed between Boulder Canyon and the Imperial Canal intake, which is some 300 miles by river. It has been asserted that although a dam at Boulder Canyon would impound the silt, there is sufficient silt in the river below it to make the silt problem continue for many years in the Imperial canals. I should also like to have Dr. Durand's opinion on the effect of floods in the Gila River, taking account of the fact that floods in the Gila take place at different times from those in the main stream.

Merely from an engineering standpoint, the first dam on the stream should be built in the upper reaches so the floods would be controlled and the foundation problems of lower dams be made much easier of solution. However, when one considers the related problems of power and flood control, indications point to a dam in the lower reaches of the river. If there is any justification in building a high dam at Black Canyon, it lies in the nearness to the power market in southern California.

The proposal for a dam at Boulder Canyon comes from the Reclamation Service and has been taken up principally by the city of Los Angeles to provide, at the expense of the national treasury, a power plant for the Bureau of Power and Light of Los Angeles and to furnish energy to pump the water from the river to the city. There are engineers of the Federal Power Commission who advance other opinions regarding the development of the river. The proposal for the all-American canal comes from those who, in their endeavor to control the waters of the river, would break our national faith with Mexico. There are also some 200,000 acres of land additional to the present Imperial Valley which are to be irrigated. As this land is, to a considerable extent, in private hands, the project of a donation of some $35,000,000 from the national treasury appeals with convincing force to the owners of the land. These are the interests behind the all-American canal and the Boulder dam and power plant. They are all hiding behind the real necessities of the Imperial Valley for flood control. If the problem was one of flood control only, it could be solved by a dam downstream from Boulder or Black Canyon.

My objection to the whole scheme lies in the endeavor to put the National Government into the power business and to build at the expense of the national treasury, works for the private benefit of certain individuals or the city of Los Angeles. I believe this to be in distinct violation of national policy, which should be at all times to keep the National Government—and, in fact, any form of government—out of business. When government enters business, it does so at the expense of, and in competition with, some of its citizens. In this way it abdicates its position of impartial arbiter between citizens and uses the power of government to destroy the property of some of its citizens. The rapid increase of power centralized in Washington is one of the most disquieting features of American life. Sometimes I am led to the conclusion that it would be better for every one concerned if every square inch of land in the western states, together with every drop of water, was taken completely

[2] Civil Engineer, San Francisco, Calif.

out of control of the Federal Government and put into the hands of the states. At the present time Arizona objects (possibly on not-well-founded grounds) to the building by the United States Government of a dam and power plant at Boulder Canyon. Arizona may be wrong in her position, but it is a bad thing on the part of the National Government to use its power to coerce one of the states.

One other point appeals to me in regard to the water available at the proposed power plant. The Santa Fe compact provides for a subdivision of the water by which one-half is allotted to the upper-basin states. Roughly speaking, Arizona is entitled to one-half of the remaining portion. This would leave California with a portion a little more than one-fourth of the entire flow of the river. If these waters be taken out of the stream, the amount of energy calculated as available at the Boulder Dam would be correspondingly reduced. I doubt very much if any careful engineer would advise any client to build a dam and power plant at large expense where the water supply is thus placed in jeopardy.

There is much difference of opinion on the subject of the development of the Colorado. Dr. Durand has set forth the subject in his usual clear manner as seen from one standpoint. I have found only one point of agreement in the whole subject, and that is that every one along the river is perfectly willing to have the United States treasury furnish the money for anything that is proposed.

FRED H. TIBBETTS.[3] I should like to call attention briefly to the irrigation situation as it effects our people and Mexico. Under present conditions the unregulated flow of the Colorado River is barely sufficient for the needs of the approximately 600,000 acres now under irrigation, 400,000 of which are in the United States and 200,000 in Mexico. By agreement this water may be equally divided between Mexico and the United States. As the upper end of the Imperial Canyon goes through Mexico, they get the first chance at the water. As there is insufficient water to extend the total irrigated area, and as the Mexicans have a right to one-half of the water, it becomes obvious that if they exercise this right and develop additional land in Mexico, it must be at the cost of the abandonment of a similar area in the United States.

To prevent the Mexicans from making still greater use of the Colorado River as the Boulder Canyon project makes available more water for irrigation, it is necessary that the all-American canal be built, so that the Americans and not the Mexicans will physically have the first chance to get the water. If we believe that American institutions are superior to those of Mexico, we must not permit the continuance of a situation which enables the Mexicans to develop more land with the certainty that such development will ultimately be at the expense of a corresponding development of similar areas in this country.

There is nothing new in the limited extent to which the Government is allowed to take advantage in the proposed Boulder Canyon project of the big power revenue possible. Nearly all of the major water developments in California, and practically all of the agricultural developments, are based on almost identical principles. Cheap water supplies in California have been exhausted. Natural streamflow has all been used up. That was the condition reached in the San Joaquin Valley about a decade ago. It was reached before that in southern California. It has just been reached in the Sacramento Valley. Important water-supply developments everywhere in California from now on involve the reservoiring of water.

As water is reservoired and stream-regulated, power can be developed at the reservoir sites and below, and it is possible for agricultural developments economically to proceed only by taking advantage of that fact. The major recent developments in California are those which follow along exactly the same lines as those proposed at Boulder Canyon. Important water-supply developments which have been financed by power include the South San Joaquin, Oakdale, Turlock, Modesto, Merced, and Nevada irrigation districts, and the municipal projects of Los Angeles and San Francisco. They all involve a revenue which will help to pay, or will completely pay, for the reservoiring and storage developments of water.

As a matter of fact, the National Government is already involved in carrying out this principle, and I am emphasizing this because the only objection among the great majority of people who are opposed to this bill is that it permits the Government to take advantage of the fact that you can get a big power revenue from Boulder Canyon.

Already there are twelve Government projects operating fifteen Government power plants, so that there is nothing new about the Government building power plants along the banks of rivers.

The Swing-Johnson Bill allows the Government, if necessary and desirable in the opinion of the Secretary, to build a power plant, but it also allows any private corporation or any one wishing to develop power to build a power plant at Boulder Canyon. It does not put the Government into the power business. It simply puts the Government in a position where it can, because of the provision that it may build a power plant, get an adequate price for the power which will pay for the project.

The half of this state south of Tehachapi considers the solution of the Colorado River problem a matter of life and death to them. The southern part of the state believes that some action on the Colorado River will be necessary within the next few years for the preservation of the very existence of Imperial Valley and for the future growth of Los Angeles. Four months ago Mr. Mulholland, the veteran builder of Los Angeles, who since 1886 has been city engineer of that city, and who has watched it grow from a country town of 130,000 people to one of the finest urban developments in the world, advised against any further extensions of the city of Los Angeles—think of that! the city engineer advising against extending the boundary lines of the city of Los Angeles—because, he said, "we cannot give them any more water until we get the Colorado River water." The best estimates, in round numbers, are that the complete development of the Owens River cannot supply over 400 second-feet more, and possible extensive developments to the north in the Mono Basin, another 180 to 200 second-feet. Then they are through, and the growth of Southern California is through. Los Angeles and vicinity, in the opinion of those best informed, require additional water in the next six or seven years, or their growth has got to stop. At the best, at the rate things move in this country—particularly political measures—it will be at least six or seven years before it will be possible to reservoir and develop more water on the Colorado River for that purpose. Hence there is no time to lose there.

H. W. CROZIER.[4] I consider that the year 1927 has seen a great change in the attitude with which this project has been regarded. We all recall the meeting at Santa Fe conducted by Secretary Hoover, the great patience of that able gentleman, and the long period which it took to work over the various hearings. Out of that meeting grew the Santa Fe compact. One of the outstanding things this year has been the appointment of the fact-finding committee. Following their appointment came the meeting of the governors of the seven states, and a great many

[3] Civil Engineer, San Francisco, Calif.

[4] Consulting Engineer, San Francisco, Calif. Mem. A.S.M.E.

things were settled. Recently in San Francisco the costs of electric power were gone into by engineers representing three of the lower states, and when those meetings were completed and facts ascertained the order of difference was less than 10 per cent. I think 1927 represents great progress. It has been a great pleasure to listen to Dr. Durand—the figures he has given as to costs are, I believe, very conservative, and give every evidence of having been carefully compiled.

Dr. Durand. I have not attempted to make any definite estimates of the amount of silt in the river below Boulder Canyon dam, but I do not expect that the Imperial Valley will be free of silt in 5 or 10 years. I assume there may always be some residual silt in the Colorado River.

With regard to the floods in the Gila, it is confidently thought that certain projects under way will control them. The total flow in the Gila is small as compared to that in the Colorado. The floods are quick and flashy and of relatively small volume, and the Interior Department believes that the projects under way will adequately control floods in that river.

Control of any river is naturally in the upper stretch. There is no question as to what should be done under ideal conditions; but where the conditions are not ideal and there are other conditions to be met, then we have to make the best of the situation. I do picture a dam at or near Glen Canyon as perhaps stage No. 2 in the development of the river, and when that dam is complete, it will greatly facilitate the construction of other dams on the lower river, and add in large degree to the value of all such projects.

With regard to silt storage, we should have at least a 40- or 50-year-life pocket. If we had a dam that would hold 7,000,000 or 8,000,000 acre-feet, we should be able to take care of the silt for a long period of years. The point is that before that time has elapsed other projects are going to be built. The first one built will naturally have to carry the entire silt burden, but with other projects built further along the river the silt burden will be divided. Again, suppose that after 60 or 75 years the capacity of the Boulder Reservoir should be seriously impaired; it would then be a simple matter to add 50 ft. to the height of the dam, with another 7,000,000 or 8,000,000 acre-feet added to silt-storage capacity.

The Thames Flood

LAST January's disastrous flood led to a conference of the various public authorities concerned, which appointed a committee to examine in detail the causes of the catastrophe, and to make recommendations as to what action should be taken in the future for the protection of low-lying areas. This committee included representatives of the Admiralty, the Meteorological Office, the Home Office, and of the Ministries of Agriculture, Health and Transport, as representing the national government. The Port of London Authority, and the L.C.C., were also represented, as well as five of the local authorities more immediately concerned.

This committee has now issued a report which includes a highly interesting review of the past history of Thames floods, some of the records dating as far back as the thirteenth century. The flood of 1663 is stated by Pepys to have been the greatest ever remembered, all Whitehall having been flooded. Apparently, however, the level reached on this occasion was not more than 16 ft. 10 in. above ordnance datum. This level was not exceeded till 1874, although old London Bridge was finally demolished in 1834. A still higher tide was recorded in 1875, when the water rose at Westminster Bridge to 17 ft. 3 in. above ordnance datum. The consequent flooding caused great damage and hardship, but there was no loss of life. Other exceptional tides were recorded in the two succeeding years, and authority was accordingly obtained for the construction of flood-protection works. It was at first thought that a height of 17 ft. 6 in. would be sufficient for these, but this level was actually attained by the tide in January, 1881, and this led to the level for protection works being increased to 18 ft. above ordnance datum. In December, 1927, the tide reached a level of 17 ft. 3 in. above ordnance datum, but there was no flooding. This December tide was the highest for forty-three years, and justified the assumption that the existing protection works were adequate.

It is very significant, however, that the average tide level at up-river stations has been steadily rising for the last thirty or forty years. The figures seem to indicate that the river improvements have facilitated the run upstream of the tidal waters.

A striking feature about the disastrous flood of January 6–7 last, lies in the fact that not merely were all previous records exceeded, but the excess was unprecedentedly large. Its abnormal height was apparently due to exceptional meteorological conditions. There was a strong northwesterly gale in the North Sea, and a westerly gale in the Channel, and there was a great deal of flood water coming down stream. The predicted height of the tide at London Bridge was 12 ft. 5 in., but a level of 18 ft. 3 in. was actually attained. At Richmond, the normal height would have been 13 ft. 10 in., while the tide actually rose to 18 ft. $6^3/_4$ in. At Tilbury again, the water rose 5 ft. 6 in. above the predicted level, and both here and at London Bridge high water was attained half an hour before the predicted time.

The committee consider it essential that an effective system of warnings should be established, but realize the danger of "the call of wolf." The 43 years of immunity indicate that it will be very difficult indeed to give only absolutely necessary warnings. They have, however, framed a scheme which they hope will be effective. An obvious proposal is to evacuate dwellings in low-lying areas, but this would be strongly resented by their present occupants, many of whom are riverside workers and prefer to live near their work. It is suggested, however, that in the case of new dwellings erected in the danger zone, the local authorities should have power to fix floor levels at a safe height.

With regard to existing protective works, these are now being thoroughly examined, and in future will be regularly inspected. A difficulty arises from the fact that it may not in all cases be possible to raise the height of protective walls without at the same time increasing the width of the base. If this proves necessary, the cost of the work will be greatly increased, and if required for the whole length of the river within the London area, may well amount to millions of pounds.

One of the problems with which the committee was asked to deal was the probability of a repetition of January's flood. They report, however, that the existing data are insufficient to provide a satisfactory basis for expressing an opinion on this head, and have advised that the whole subject of tides on the Thames requires additional expert investigation, and have recommended that this work should be undertaken by the Liverpool Tidal Institute, working in cooperation with the Hydrographic department of the Admiralty, and with the Meteorological Office. The cost of this investigation will be shared by the Port of London Authority and the London County Council.—*Engineering*, March 9, 1928, p. 294.

High-Pressure Steam Boilers

A Study of the Principles Underlying Their Design and Construction

By GEO. A. ORROK,[1] NEW YORK, N. Y.

After briefly referring to the work of Münzinger, Hartmann, and Mellanby and Kerr, the author proceeds to discuss the lines of further investigation which to him seem to offer the most promise. In so doing he discusses the effect of tube inclination; the circulation problem; releasing surface and steam space; safety in operation; increase in capacity; boiler materials; temperature margins; and stresses in superheater tubes, riveted drums, and headers. Among other things it is brought out by this discussion that (1) a high-pressure boiler must consist largely of banks of tubes; (2) that headers in great variety are available up to at least 1400 lb. pressure; (3) that drums must be of small diameter and should not contain over 10 per cent of the water content of the boiler; (4) that below 1000 lb. there is no need of employing alloy steels, but above that pressure such steels are available and should be used if the temperature margins so require; (5) that for superheats higher than 800 deg., alloy steels are indicated; (6) that 20 or more different designs of boilers are successfully operating at pressures of 500 lb. and over, six at 1000 lb., and one at 2000 and over; and (7) that enough work has been done to show that their efficiencies are comparable to those obtained with boilers of lower pressure. In closing, the author states his conclusions as to the type of high-pressure boiler best suited to present limitations.

SOME years ago in a paper presented to the Society the author commented on the "Possibilities of High Pressure and Temperature in the Central Station," and came to the conclusion that much higher pressures were a commercial possibility but that we had reached about the limit as to temperatures until constructional materials other than the usual boiler steels were available. In February of this year in a paper before the Midwest Power Conference he presented a list of forty installations of boilers operating at above 500 lb. pressure, and from the operating results came to the conclusion that the higher-pressure operation was justified from both the thermal and commercial point of view.

It has often been stated that the customary boiler designs which have been found so suitable and satisfactory for the ordinary pressures (150 to 400 lb.) would be at a great disadvantage when much higher pressures were considered and such constructions as the Schmidt, Blomquist, Loeffler, and Benson boilers have been developed to meet the difficulties which the ordinary types presented. In this country the Weymouth and Milwaukee boilers (1200 to 1400 lb.) are a development of the standard types, and the very real difficulties of construction have been overcome by the selection of costly materials and the use of thickness of metal never before attempted in boiler constructions. Münzinger, in his paper at the World Power Congress, investigates the materials and designs of two common types of boilers for various pressures, and stresses the steam accumulator as being necessary with the smaller-water-content sectional boilers. The papers of Hartmann (*V.D.I.*, 1921, No. 26, p. 663, and "Hochdruckdampf" (*V.D.I.*, 1924), Jacobus (World Power Congress), and that of Mellanby and Kerr (Proc. I.M.E., 1927, p. 53) bring the discussion of high-pressure steam generation and boiler construction up to the present time. Nevertheless it appears to the author that none of the preceding authors has laid down basic principles, nor indicated the general trend which successful design and construction should follow. This paper is an attempt to bring the problem nearer to solution by suggesting the lines which to the author appear to offer the most promise.

In practice it has been observed that all reasonable boiler designs can be made to operate at a reasonably high degree of efficiency. Boilers of such wide difference in design as the Lancashire type and Babcock & Wilcox type when tested by careful experimenters have developed equally high efficiencies. The design problem then becomes a question of capacities versus costs, and the smallest and lightest design of equal strength and capacity is, within limits, the best commercial proposition. Certain operating desiderata must also obtain. Inspection and cleaning must be easy, circulation must be sufficient, the gases must be brought into intimate contact with the heating surface throughout their course in the boiler, and finally steam-making, superheater, economizer, and air-heater surfaces should be proportioned for the work the boiler is designed to do. From the manufacturing side the parts making up the boiler should be small but not too small, combining light weight with strength (i.e., drawn tubes and cylinders), easily and quickly put together and easy to replace. It is from such considerations as these that the modern water-tube boiler has developed. As a rule these boilers today consist of a steam drum or drums, a nest of tubes connected to the drum directly or by front and back headers of various constructions, and a mud drum. Integral superheaters and economizers may accompany this construction, or a portion of the tube surface may be used for these purposes. The arrangement and the proportioning of the separate parts vary greatly.

In studying the various design of tubular boilers it appears that most of the water content of a boiler is contained in the tube bank, the drums rarely containing as much as 15 per cent of the total water content. In general the weight of water in a boiler with 1-in. tubes will not exceed 0.9 lb. per sq. ft. of heating surface, which increases to about 3.5 lb. per sq. ft. of surface for the standard 4-in. tube and is directly proportional to the internal diameter of the tube. Multiple drums, outside downcomers, large mud drums, and water-wall headers may increase these figures.

Effect of Tube Inclination

Many experiments have been undertaken to determine what inclination of boiler tubes is most conducive to evaporative capacity and efficiency. The Babcock & Wilcox Company after exhaustive experiments with slopes varying from 5 deg. to over 20 deg. have chosen 15 deg. as their standard. The Heine Boiler Company and the Edge Moor Boiler Company use a slope of $4^1/_2$ deg., approximately, as do most boilers of the stayed-header type. In the Parker, Belleville, and several other boiler types the slope is nearly horizontal. In the Wickes and certain other boiler types the tubes are nearly vertical, and the Hornsby, Stirling, and Garbe types use all slopes from 45 deg. to the vertical. As a matter of fact, equivalent efficiencies have been obtained with tubes of practically all degrees of slope.

Circulation

In shell boilers the circulation problem is quite serious, and

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many troubles have developed from this source, resulting in the introduction of mechanical aids to circulation such as the hydrokineter, but with the water-tube type these difficulties do not appear to be of much moment.

We may take it as a fact that with water-tube boilers, circulation may be rapid or sluggish, depending on the arrangements which the designer has used, and that the more nearly the boiler approaches the flash type, the slower is the circulation. As a corollary to this conclusion we can state that the water content of a boiler and the necessity for speed in circulation increase with the departure in type from the flash boiler and must be at

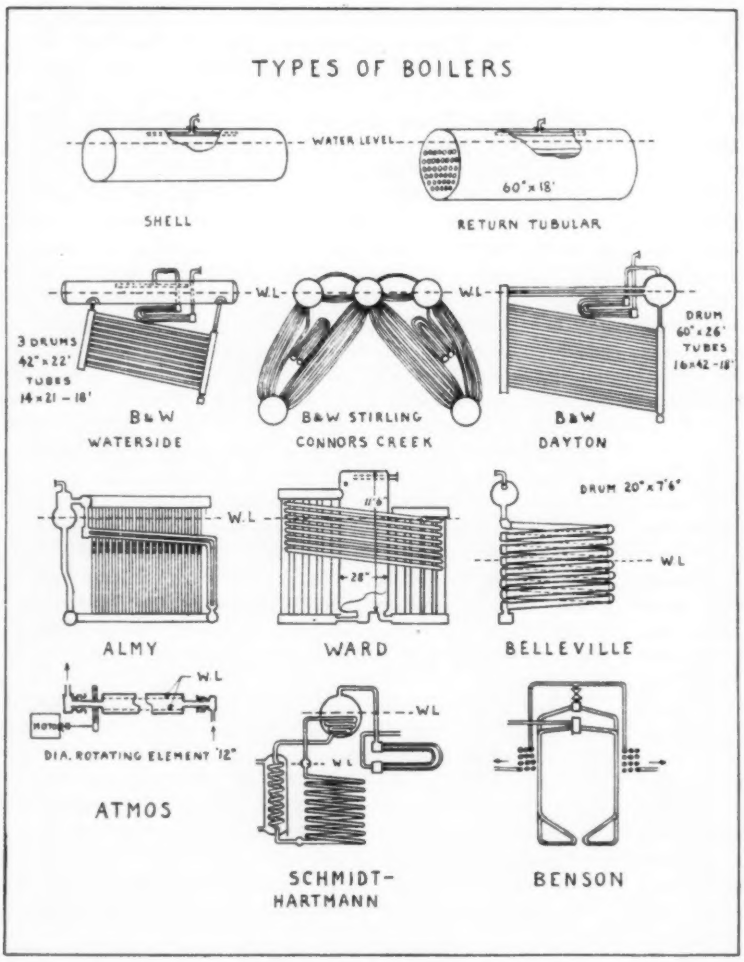


FIG. 1 TYPES OF BOILERS

their maximum in a shell boiler. Münzinger and other authorities agree with Albans that the size of the steam bubbles and therefore the percentage of vapor in the tubes decreases with increase of pressure. His curves show that the percentage of solid water increases largely with the pressure—thus the circulation at high pressures may be more sluggish without detriment to boiler operation—and this leads to the Benson contention that the best results should be obtained at the critical point (3200 lb.) where steam and water have the same density and therefore no bubbles exist and no line of demarcation can be drawn between water and steam.

Releasing Surface and Steam Space

It is usually stated that there must be a water surface of sufficient area to release the steam bubbles from the water to prevent priming, and that a steam-storage space must be provided to allow the water particles not evaporated but entrained in the steam to settle out. The usual allowance for steam space in a shell boiler is about one-third of the volume, and the ratio of heating surface (HS) to releasing surface (RS) is HS/RS = 3.5. This ratio in the ordinary return tubular boiler is 17, in the standard three-drum 14-high 21-wide Babcock & Wilcox is 31, in the Babcock & Wilcox cross-drum type, 96, in the Connors Creek Stirling, 71, and in the boilers of the Almy, Ward, and Belleville types, from 2000 to 7000. As all of these boilers prime occasionally and all can be run without priming, it will be seen that releasing surface has nothing to do with priming. As a matter of fact, priming will not occur unless the boiler is impure or soapy due to the presence of colloids. Entrained water is a different thing and will occur in all boilers to a greater or lesser degree, depending on the location of the tubes entering the drum and the dry-pipe arrangements. Efficient dry pipes are an essential part of all boilers, and the greater capacity (higher rating) obtained requires a better and more liberal design of dry pipe. Steam domes and steam drums in addition to the ordinary drum have been used to assist in obtaining dry steam. Superheaters should not be used for evaporators, and the releasing surface should be such that particles of water under maximum conditions should not reach the dry pipe.

The steam-space ratio (HS/SS) also varies largely—from about 4 in shell boilers, 22.5 in the longitudinal-drum Babcock & Wilcox, and 50 in the Babcock & Wilcox cross-drum to over 100 in the Belleville and 150 in the Ward, and was very large in the earlier Belleville boilers and almost infinity in the Herreshoff coil boiler and other flash boilers. All of the high-ratio boilers made special provisions for feedwater regulators and safety valves, and these features appear to be necessary for operation.

It should be noted that either a time element (i.e., steam-storage space) or pressure reduction (i.e., throttling of the steam) appears to be necessary to good running. In the drum types the steam must rest for a short time before entering the dry pipe, while in the Almy, Belleville, and coil types the steam nipples connecting the boiler tubes to the steam drum or dry pipe are extremely contracted in area, so that there is a large pressure drop and consequent drying or superheating of the steam. Similar action takes place in the passage through superheaters, and in many boiler types the steadiness of steaming is greatly enhanced by this effect.

The earlier boiler builders understood these facts very well. Watt, Albans, and Bourne allowed from 8 to 10 sq. ft. of heating surface per cu. ft. of water evaporated per hour. This corresponds roughly to 200 per cent of rating (6.25 lb. to 7.8 lb. evaporated from and at 212 deg. per sq. ft. of heating surface). Their rule for releasing surface was 5 sq. ft. per cu. ft. of steam per sec., which corresponded to 37 sq. ft. per 1000 lb. of water evaporated per hour in the atmospheric boilers of Watt. At 200 lb. gage the figure is roughly 3 sq. ft. per 1000 lb. per hour while at 1200 lb. the surface is 0.5 sq. ft. per 1000 lb. evaporated per hour. Considering the 200-lb. boilers (in Table 1) the 3 sq. ft. per 1000 lb. per hour is 5 cu. ft. of steam per sq. in. of releasing surface per hour. The table shows normal values of ten times this ratio at 100 per cent of boiler rating. On the actual maximums, twenty to thirty times the early figures are shown.

DeLaval and Serpollet, working at or above 1000 lb. per sq. in., had no trouble from lack of releasing surface or steam-storage space. The Serpollet steam and water passages were $^5/_{32}$ in. wide, and the water contents very small indeed. Boilers with tubes as small as 1 in. O.D. work very well in quite large sizes, but 2 in. is about as small as has been used to any extent in land practice, although Yarrow used $1^3/_4$-in. tubes in the Dunstan and Barking boilers. The Almy boiler has a ratio one-twentieth as large, while the Ward and Belleville boilers have a releasing surface only about one-hundredth as large as Watt's standard. These two types have very restricted circulation and the releasing surface is in the tube, but they were able to carry heavy loads without serious entrainment troubles. Many boilers have been operated at 150 cu. ft. of steam per sq. in. of releasing area per hour, or a steam velocity leaving the water surface of 6 ft. per sec., and a simple calculation will show that at this rate the tube area itself furnished ample releasing area. This same calculation will show that a 4-in. water-wall tube 70 ft. long will have sufficient releasing area in itself if the water level is carried in the tube, a fact which has been a stumbling block to some designers. Similar calculations also show that conditions improve with increase of pressure.

Watt and Bourne allowed a volume of 20 times the high-pressure cylinder for the steam space. At the steam speeds in vogue at that time this allowance was equivalent to about one minute's storage in the steam drum, but this rule was not followed and ratios of (HS/SS) instead of being 4 were of the order of 12 to 16 as in our return tubular boilers. Since the invention of the turbine, intermittent-flow troubles have ceased and the ratio may be much larger.

In general, because of the lower specific volume, high-pressure steam needs much less releasing surface and steam space than low-pressure steam. Boilers should work much better at high pressure, and much less trouble is to be expected with increasing pressures.

Safety in Operation

As a general rule, that design is the safest which has the smallest volume of water content, since "superheated water" is the chief source of danger in a boiler; therefore drums should be made as small in diameter as possible in order to avoid this danger. The tearing of drum sheets, so common in explosions of low-pressure boilers, allowing large volumes of superheated water to flash into steam, should not occur in high-pressure work. It has been observed by all operators of high-pressure boilers that split tubes or bulges which open do not lead to explosions. In many of the cases reported the fact of the split tube became known only by the extinguishing of the fire, the slight hissing noise not having been noticed by the operator until after the fire had been extinguished.

Increase in Capacity

The most important development in boilers in the twentieth century is the great increase in capacities which are now being secured from all types of modern boilers. Improvements in furnaces, water-cooled furnace walls, and combustion control, and the introduction of powdered coal have enabled the boiler operator to increase greatly the 7 lb. of water evaporated per hour per sq. ft. of heating surface recommended by Watt, which had been cut in half by the Centennial Boiler Testing Committee. Fifteen to twenty pounds at good efficiency has now been secured, and 25 to 30 lb. is in sight. This condition exaggerates an operating difficulty more or less common in earlier boiler plants, namely, the "loss of water" or the lowering of the water level in the boiler drum below the gage-glass level when the forced draft failed or the coal feed was interrupted in the powdered-coal installations. In most modern boilers less than 15 per cent of the water is contained in the drum, and when steaming at a high rate more than 20 per cent by volume of the water is steam bubbles. As long as the operation is continuous no troubles are encountered, but in an emergency when the coal feed is interrupted or the forced draft is cut off the bubbles are absorbed and the water contracts rapidly, the water level falls, and the automatic feed regulators open wide, filling up the drum. When steam making starts, the volume increases, the water level rises, water enters the dry pipe, and slugs of water may pass

TABLE 1 DATA ON MODERN BOILERS

Types of boilers and drum sizes	SS Steam space, cu. ft.	RS Releasing surface, sq. ft.	HS Heating surface, sq. ft.	$\frac{HS}{RS}$	$\frac{HS}{SS}$	Weight of water in boiler, lb.	$\frac{W}{HS}$	W Water evaporated per hour, lb.	Time to evaporate boiler content min.
			Steam Pressure, 200 Lb. per Sq. In.						
Belleville (S.S. *Charlemagne*), 20 in. × 7 ft. 6 in., 7 elements, 16 tubes	16.5	0.61 (a)	1,800	2950	109	3,500	1.95	14,220	14.7
Ward (U.S.S. *Monterey*)	18.0	0.45 (a)	2,970	6670	165	5,360	1.81	20,100	16.0
B. & W. (U.S.S. *Cincinnati*), cross-drum 42 in. × 12 ft.	58	42	2,640	63	45.5	9,480	3.59	30,760	18.6
Stirling (Connors Creek), two 48 in. and 154 in. × 28 ft.	576	350	25,000	71.5	43.4	66,000	2.64	149,600	26.5
Almy, 66, $1^4/_{16}$-in. tubes	37	0.47 (a)	1,386	2950	37.5	1,850	1.34	3,230	34.0
B. & W. (Dayton), cross-drum 60 in. × 26 ft.	255	130	12,500	96.3	49.0	84,240	6.75	91,200	55.4
B. & W. (Waterside), three 42 in. × 20 ft.	288	210	6,500	31	22.5	51,210	7.88	54,900	56.0
Return tubular, 60 in. × 18 ft., 125 boiler hp.	70	76.5	1,250	16.6	17.9	16,100	13.4	5,620	171
			Steam Pressure, 250–400 Lb. per Sq. In.						
Ladd (Fordson plant), 7-drum 60 in. × 27 ft., 54 in. × 28 ft., 36 in. × 25 ft.	1151	522	29,500	56.5	25.6	206,000	7.0	97,000 (b) / 460,000	128 / 27
B. & W. (Colfax), cross-drum 60 in. × 33.7 ft., 20 × 47 tubes	330	165	29,780	181	90.5	113,000	3.8	98,000 / 300,000 (b)	69 / 22.5
B. & W. (Gould St.), cross-drum 60 in. × 32.8 ft., 18 × 51 tubes	321	161	29,070	181	90.5	106,000	3.65	104,000 / 416,000 (b)	61 / 15.3
B. & W. (Stanwix), cross-drum 60 in. × 33.7 ft., 20 × 51 tubes	330	165	32,070	194	97.0	119,000	3.72	105,000 / 300,000 (b)	68 / 24
Springfield (Hell Gate), cross-drum 54 in. × 29.5 ft., 16 × 54 tubes	235	133	13,900	104	59.2	70,000	5.04	225,000	18.7
Springfield (East River), cross-drum 54 in. × 29.5 ft., 16 × 54 tubes	231	133	17,830	134	77.2	103,000	5.78	350,000	17.7
			High-Pressure Boilers, 1200–3200 Lb. per Sq. In.						
Atmos., element, 12 in. × 15 ft.	3.0	23.5	47	2	15.7	425	9.1	2,500	10.0
Schmidt-Hartmann (SHG), 36 in. × 10 ft. 10 in.	20.7	29.0	283	9.8	13.7	2,320	8.2	3,300	42.0
Benson (SSW)	0	0	1850	8	8	680	0.37	66,000	37 sec.

(a) Water level in tubes.
(b) Evaporation at 100 per cent of rating and maximum evaporation.

through the superheater and steam mains with serious results. In flash boilers above 600 lb. pressure this difficulty is not of much moment, but at pressures from 200 to 600 lb. and high ratings as much as 40 per cent contraction may be encountered and the water level brought well down into the tube body. This has always been considered a dangerous condition, even though it is well known that Manning and other vertical fire-tube boilers carry the water level much below the tube tops, and all flash, coil, Belleville, Ward, Thornycroft, and some other water-tube boilers have the water level somewhere in the tube bank. To prevent siphoning over the auxiliary steam drum, multiple drums as in the Borsig and similar designs or an increase in the size of the main steam drum will obviate the difficulty. The latter two devices do not appear to be good practice, since they increase the water content and multiply the sources of danger from superheated water. A number of methods of working the feedwater regulator have been suggested which can take care of this condition in a better and easier way, and such devices are being developed. It is also a question whether a dropping of the water level into the tube bank of high-pressure boilers is a dangerous proceeding. To the author such a procedure is much less of a menace than an additional drum with its content of superheated water.

Boiler Materials

As an appendix to the paper on high pressures and temperatures before referred to, the author gave a résumé of the knowledge then available on the variation of strength of boiler materials with temperature. This body of facts has been largely augmented and the newer theories of fatigue and creep have been developed. Fatigue phenomena are apparently reasonably consistent, and only rarely enter into the boiler problem. Creep phenomena, on the other hand, are still highly controversial, some authorities holding that creep does not occur below certain limited stresses which may be well above the limits of proportionality. The opposing theory that creep occurs at all temperatures and stresses and that the condition must be chosen to limit the creep to safe values over a period of time, is also strongly held. Mellanby, Lea, Tapsell, and others in England and France, and Lynch, Malcolm, McVetty, White, and others in America, have presented excellent papers in which the known facts and theories have been ably discussed. The diversity of opinion is best shown by the curves of Fig. 2, where curves obtained from various boiler materials are shown. Since the "creep limit' is usually placed at or around the proportional limit, or perhaps the yield point, or something around these figures, the actual yield point of tube steel as manufactured by the National Tube Company is also included. From many observations of actual boilers the author's own preference is for the curve of French, and he has used it in calculations for factors of safety for temperatures.

It has long been known that the modulus of elasticity E—Young's modulus—varies with temperature, experiments as far back as 1860 having been conducted to obtain values of E at boiler temperatures. Martens in 1886 conducted similar experiments. Most of the early results gave a straight-line formula quoted in Kaye & Laby, and Sutherland's formula came later. However, all experiments became uncertain above 1200 deg. fahr., which is near the first recalescence point. A discussion of all obtainable experiments leads to two formulas, one a straight-line formula for alloy steels, and the second a modified Sutherland formula which represents fairly well the low-carbon boiler steels up to 1200 deg. fahr. This formula is:

$$\frac{E_t}{E_{32}} = 1 - \frac{(t-32)^2}{1700}$$

It is highly probable that the elastic law does not hold at increasing temperatures; indeed Bailey in his paper before the I.M.E. on April 21, 1927, states: "The relation between stress and strain will no longer be represented by Hooke's law, but an exponential expression tending toward this law at low stresses."

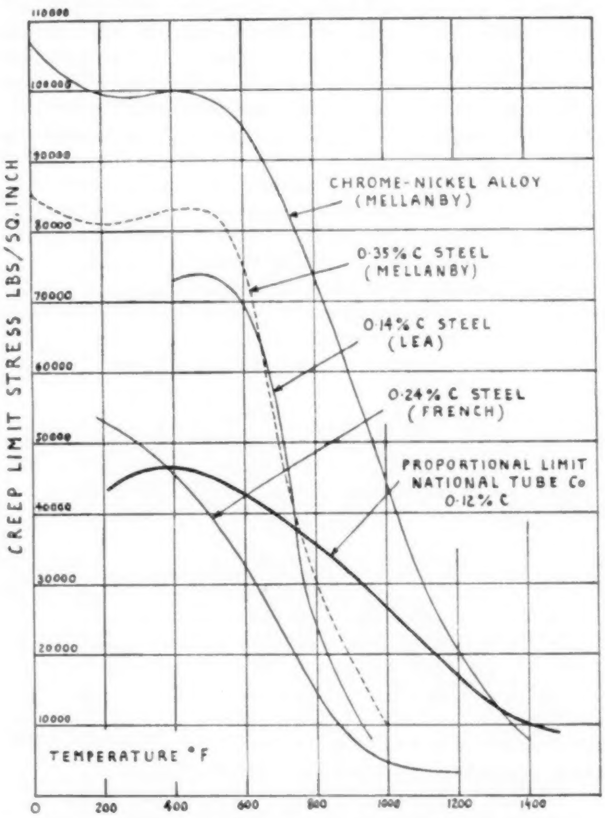


Fig. 2 Creep Limit Stresses at Various Temperatures

He also concludes that there are good reasons for expecting better service from metals at high temperature than would be expected from elastic considerations, citing the Langerbrugge experience as an example.

Temperature Margins

Mellanby and Kerr in their 1926 I.M.E. paper showed excess temperature margins in boiler, water-wall, and superheater tubes, from which they drew the conclusion that the temperature margin with the ordinary boiler steels was too small and that the use of alloy steels was indicated when higher pressures and temperatures were to be used. They developed formulas for and calculated heat strains in addition to the pressure strains in the body of the tubes. Their figures are made on 0.35 C steel, while the author's are on 0.12 to 0.15 C National Tube Co.'s steel. Comparative temperature margins on 4-in. boiler tubes at 108,000 B.t.u. absorbed per sq. ft. per hour are as follows:

	Pressures			
	200 lb.	600 lb.	1000 lb.	1400 lb.
Mellanby	420 deg.	275 deg.	180 deg.	120 deg.
Orrok	480 deg.	300 deg.	200 deg.	100 deg.

From experience obtained with different boilers at high- and low-pressure stations both here and in Europe it would appear that a 200-deg. temperature margin is safe for all ordinary work, particularly as 100,000 B.t.u. per sq. ft. per hour is above the maximum ever obtained in any of the experiments except the plate experiments of Witz and Nicholson, which do not represent

boiler conditions. The experiments of Witz are very interesting since the point of the inner cone of the Bunsen flame which he used impinged on the surface of the plate, a condition similar to the blowpipe action shown in a forced-draft installation with small holes in the fire bed. When the flame point touched the tubes the outer surface of the metal became red hot and resulted in local bulging or a split tube. The flame temperature at the point of the inner cone is of the order of 3000 deg. fahr. or higher, and this action was well known as far back as Alban's time. The temperature of the outer cone is much lower, but in all cases the flame should not impinge directly on the tube surface. The absorption of radiant heat is usually sufficient to reduce the gas temperature to a safe figure. In this connection it is instructive to note that high-pressure tube failures, i.e., explosions, invariably occur in very limited areas and usually make themselves known by putting out the fire. The openings are usually very small, and probably the higher velocity at the point induced by the outflowing steam introduces sufficient cooling action to prevent the spreading of the opening.

Stresses in Superheater Tubes

Convection superheaters show very low heat-transmission rates, the maximum reported being about 6000 B.t.u. per hour per sq. ft. for a straight convection superheater, which has only been increased to 8000 to 9000 for the usual interdeck variety. Steam velocities must not fall below 40 to 50 ft. per sec. or the temperatures of the outer and inner surfaces will equalize and tend toward the gas temperature. This fact was well known very early, and was the reason for flooding during the warming-up period. For standard conditions in convection-type superheaters (750 deg. fahr. total temperature) the temperature margins are of the order of 400 deg. fahr. for 200 lb., and around 200 deg. fahr. up to 1400 lb. This figure has been calculated for a heat transfer of 10,000 B.t.u. per hour per sq. ft. Radiant-heat superheaters suffer much more severe punishment since the transfer rates may be as high as 60,000 to 70,000 B.t.u. per hour per sq. ft. although the highest reported rate is around 30,000 B.t.u., and the tube is frequently exposed to the flame tips, both inner and outer, as well as to direct radiation. Temperature stresses play a very important part, and the total stress is about twice that occurring in a convection-type superheater for the same pressure. The temperature margin has been reduced to 250 deg. fahr. at 200 lb., is only 200 deg. at 500 lb., and 100 deg. at 1200 lb. Under these conditions the life of the superheater tubes must be much shorter, and bulges and failures must occur at short intervals with comparatively low pressures. Flooding is dangerous even at the lower pressures, and would probably not increase the life of the superheater tubes materially. No attempt has been made, so far as is known to the author, to increase steam speeds to the point where the 200-deg. temperature margin could be maintained. In general, with ordinary boiler material radiant-heat superheaters are much more subject to troubles than the usual convection type. Radiant-heat superheaters have been installed of chrome-nickel or chrome-iron alloys. This material has a much higher creep limit than ordinary open-hearth steel, and temperature margins of a much higher order may be obtained. Comparatively little experience has been obtained with this material, but a much longer life may be expected at a very considerably increased first cost. A number of such installations are at present in use in this country, and Mellanby and Kerr in England recommend the use of similar material. Radiant-heat superheaters of cast steel and forged steel of the rectangular box type are also in use. Here the stresses are indeterminate and the reported results have been satisfactory, although length of service has been too short to determine safe life limits.

Riveted Drums

The strength of riveted drums as prescribed by the Boiler Code is determined by the efficiency of the joint, which may vary from 80 to above 90 per cent. Allowing 80 per cent for the joint efficiency, the code formula with 54,000 lb. tensile strength steel becomes $PD/17{,}250 = t$, where t is the thickness of plate used. Pipe connections to headers or tube holes must be provided for, and thus the ligament spacing becomes the determining factor. Either reinforcing must be introduced or a thicker plate employed for that portion of the shell on which the tube holes are drilled. For the standard Babcock & Wilcock, Springfield, or Stirling spacing with 3-, $3^1/_2$-, or 4-in. tubes the ligament efficiency is around 43 per cent and the code formula reduces to $PD/9300 = t$. Table 3 of the complete paper shows that drum thicknesses rapidly become unmanageable and at around 1000 lb. pressure amount to more than 10 per cent of the drum diameter. The forged drums for the Edgar and Lakeside stations are over 4 in. thick for a 48-in. inside diameter, but here the steel is of higher tensile strength and the ligament efficiency is much higher than the standard 43 per cent usually employed. Hammer-welded drums of the type made by Thyssen, Krupp, and other European manufacturers offer certain advantages over forged drums. In this construction in testing, the shell is subjected to stresses above the elastic limit and the deformations are carefully measured, disclosing every weak place in the material. The shell is then carefully annealed to remove heat strains and the hardening due to cold working. Many drums of this type are in successful use in Europe for pressures in some cases as high as 2000 lb. per sq. in. Since the Boiler Code allows the use of 35,000 lb. ultimate fiber stress on welded joints of this character, the use of the welded joint will not affect thicknesses where the ligament efficiency is less than 65 per cent, as it is in most constructions. It is also generally conceded that a drum which has been tested above the elastic limit, with its deformations carefully measured, and then annealed to remove all internal stresses, is much more trustworthy than a drum bent into shape cold, riveted, and calked.

It is considerations of this sort which led the Massachusetts Board of Boiler Rules to approve the use of a similar method for determining the safe working pressure of the forged headers of the Edgar 1200-lb. boilers. In this case the allowable pressure is the cold hydrostatic pressure at the proportional limit divided by two, which corresponds roughly to a factor of safety of two and one-half on the elastic limit, and five or less on the tensile strength. Nothing was said in the Massachusetts rule about annealing the headers when permanent deflections resulted from the hydrostatic test, since the headers were tested nearly to destruction.

Drums of high-pressure boilers should be kept away from the fire. In many boilers the shells are protected by firebrick or high-temperature cement. Lower drums are protected by brick walls and arches so that their surfaces cease to be heating surface and are rarely hotter than the saturated-steam temperature. Temperature margins are thus very high, in most cases over 400 deg., with very little chance of surreptitious reduction.

Headers

The stress in rectangular sinuous boiler headers of cast, forged, or drawn steel are indeterminate, but for purposes of design they may be taken as double the stresses in a circular header of equal area and thickness, with the usual allowances for ligament efficiency, welds, and eccentricity. No design should be used without hydrostatic tests to destruction where the deflections at all weak points are accurately measured. The actual design is stiffened in most cases by fillets, ribs, and bosses. Headers are now made from welded forge steel and open-hearth cast

steel, from electric-furnace alloy cast steel, and swaged or forged from seamless drawn steel tubing. All these types are in satisfactory operation at the present time. The gas headers perhaps take a little better care of the strains as variations are very easily made in the thickness of metal and radius of fillets. Also bosses, ribs, and external and internal lips to stiffen the section are more easily secured. Alloy steels of especial rigidity and composition may be used, but would be impossible if the material had to be welded. As the header in most cases is directly exposed to the fire, heat strains enter into the problem and thickness of metal should be kept as small as possible under the circumstances. Maximum strains, however, do not occur on the hot surface where support is secured from the tubes, but on the cold side in the neighborhood of the handholes and in the oblique ligaments. The temperature margins are somewhat uncertain, but are around 400 deg. for most cases.

Superheater headers in many cases are circular in section, and the stresses are determinate and can readily be figured. The header is generally set apart from the flow of hot gases and the temperature margins are high. Even when the rectangular box is used the protection of the baffles is such that the header and joints are not exposed to a high temperature.

Water-wall headers are usually circular in section and the stress can be determined by the usual methods, ligament efficiency being the critical factor. The headers are usually made from seamless drawn sections and in some cases have been thickened on the side where the drilled holes occur, or the hole is eccentric with the outer surface, allowing thicker metal where the tube holes are drilled. In many constructions these headers are entirely outside the path of the hot gases, while in other cases the header is protected by firebrick as well as the tube joints. Temperature margins are thus large, much in excess of 400 deg.

The Massachusetts Board of Boiler Rules has considered another method for determining allowable working pressures of headers where the material of the header has been tested and the proportional limit has been determined. The formula is $P = (H \times T.S.)/5E$, where H is the hydrostatic pressure at proportional limit of the test coupon, and $T.S.$ the ultimate tensile strength. This formula corresponds to a factor of safety varying from 1.5 to 3 on the proportional limit, and gives higher working pressures as the proportional limit is a smaller percentage of the ultimate strength. The method quoted on a preceding page under the heading "Boiler Materials" allows higher working pressures when the proportional limit exceeds 40 per cent of the ultimate tensile strength, which is most generally the case. From many considerations it is better to determine the pressure which stresses the metal of the header to the proportional limit in its weakest place and consider the safe working pressure as some fraction of this test pressure depending on the amount of exposure to the heated gases. When castings or alloy steels are used the proportional limit may be more than 60 per cent of the ultimate tensile strength, showing the material is much more rigid than welded material. Temperature margins are equally high as the proportional limit does not fall off so early, although the legal factor of safety of five on the ultimate is in most cases considerably decreased. A study of the physical constants of alloy steels gives creep curves extending to much higher temperatures than those for usual boiler material. (See Fig. 2.) In other words, the temperature margins of safety are greatly increased as shown by Mellanby and Kerr.

It is now plain from our discussion that:

1 A high-pressure boiler must consist largely of banks of tubes.

2 Headers of almost infinite variety are available up to at least 1400 lb. pressure.

3 Drums must be of small diameter even when forged, and should not contain in excess of 10 per cent of the water content of the boiler.

4 Many good designs are available if the usual canons of boiler designs are followed.

5 Up to at least 1000 lb. there will be no necessity of going to alloy steels, but above this pressure alloy steels are available and should be used if the temperature margins so require.

6 High-pressure work will show less difficulties of operation than lower pressures.

7 For higher superheats than 800 deg., alloys steels are indicated.

8 Contemporary technical literature shows twenty or more different designs of boilers operating successfully at pressures of 500 lb. and over, while at least six entirely different designs are working at 1000 lb. and over. One type is working at 2000 lb. and over. There is nothing to show the best design since all these types work well and they differ only in capacity and in the care in which the details have been worked out. The test data are insufficient to show real efficiencies, but enough work has been done to show that the efficiencies are comparable to those obtained with boilers of lower pressure. An inspection of the steam table shows that the latent heat at 200 lb. is about 850 B.t.u. per lb., while at 1200 lb. it is 610 B.t.u. Regenerative heat should be used to heat the feedwater from the hotwell temperature to the temperature corresponding to 400 lb. (450 deg. fahr.). Beyond this an economizer should be used nearly up to the saturation temperature. If a sufficient amount of air heating be included in the design, little heat will be wasted, and boiler efficiencies will be maintained even at very high pressures. Actual evaporations should be higher in inverse proportion to the latent-heat content at the saturation pressure.

Conclusions as to Best Type of High-Pressure Boiler Under Present Limitations

We may now state our conclusions as to the type of high-pressure boiler best suited to our present limitations.

1 Very high-pressure boilers (2000 lb. and over). Flash type, tubes 2 in. or less in diameter, no header, no drums, all welded joints, except at collectors and manifolds where flanged or coned joints should be used. These boilers consist of a single coil for small outputs or multiple coils as in the Benson boiler.

2 High-pressure boilers (800–1600 lb.). Water-level type, consisting of a bank of tubes of larger diameter than those indicated for the flash type, with walls not to exceed one-tenth of the outside diameter in thickness. Tubes to be expanded in headers or small-diameter drums whose thickness when exposed to fire should not exceed one-tenth of the outer diameter. Waterline drum should not contain when half-full more than 10 per cent of water content of the boiler. The boiler should be high rather than low, so that the water in the tubes may be under sufficient static head to insure steadiness of steam, and restrictions in discharge opening to steam drums should be sufficient to obviate serious moisture in the steam. Dry pipes or separators should precede the superheater. Steaming economizers should not be used, but the feedwater should be heated by economizer or the regenerative system so that little water heating is left to be done by the boiler itself. Water-cooled furnace walls should be used in sufficient amount to make the furnace repairs a negligible quantity.

3 With temperatures in excess of 750 deg. fahr. we must be content with a shorter life of tubes and be prepared to replace coils or tubes from time to time. The only alternative is the use of much-higher-cost alloy steel.

[In an appendix the author develops mathematical expressions for the thermal stresses in boiler tubes.—Editor.]

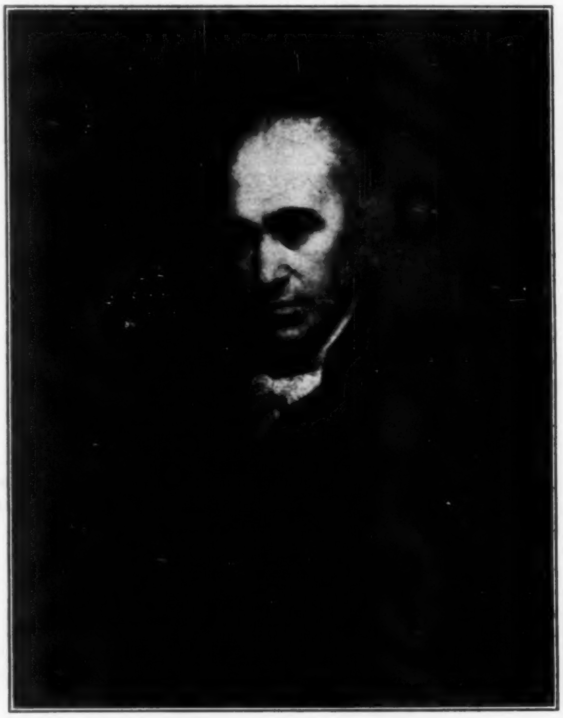
Mechanical Invention as a Form of Expression

By CROSBY FIELD,[1] BROOKLYN, N. Y.

IN DICTIONARIES and encyclopedias it is possible to find quotations from many authorities who assert that any functioning of human beings, from the lowliest folk dances of the aborigines to the final painting of a masterpiece by one of the world's great artists, is merely a form of expression. In the one case individualism runs rampant, but we cannot state that the expression has evolved a real form, or technique. In the other case we have individualism, but the form of the expression is a well-recognized technique or craftsmanship, always under the guidance of the element of individualism. Let the technique become so predominant, however, as to override too many of the established tenets of the art, and the individualism is broken down, and ceases to exist. We must therefore avoid extremes of individualism, which preclude art, on one hand, and on the other the extreme of established technique which makes for craftsmanship rather than art. We must add, therefore, to the individual concept a certain form of expression which has become established by the practice of a group of individuals working in the same general field of expression. Mechanical invention has been practiced sufficiently by persons of so many different viewpoints and activities, as to have arrived at a group form of expression that is indeed the technique of an art.

What is mechanical invention? Is it engineering? No! But it utilizes engineering. Is it mathematics? No! But it needs mathematics. Is it science? No! Science is the cruel stepmother—willing to help feed and nourish the child at times; she is more frequently ready to prove by tradition, and her so-called "accepted-facts" convention, that the child is a sport and should not survive.

One attribute mechanical invention has in common with other forms of art is in the fact that its creations are visualizations. This visualization is threefold: first, the actual figures or outlines that are the denotative aspect; secondly, the connotative envisionment of moods and other intangible forces; and finally, there is ever present, even though it is so abstract that it cannot be termed even connotative, that visualization of the effect of the work on the sum total of human activities. And all these three expressions of the visualization must be present in the object of the expression of the art, ere we can call it truly art.



James Watt (1736–1819)

Whose improvements in the Newcomen steam engine laid the basis for the almost universal availability of mechanical power which has emancipated modern man from the slavery of physical labor and immeasurably increased his material wealth and comfort.

It is chiefly in the last two aspects that the mechanical invention differs from the painting, and this difference is due mainly to the concreteness or reality of the effects of this visualization. The picture requires the interpretation of the man to create the concept of these two aspects; prior to the birth of the machine, while it is still in the picture stage, the man is required, but once born, once a real machine, the man is thrown aside; the machine itself interprets the threefold aspects of its visualization in which all the effects will follow, regardless of the presence of the human interpreter.

Consider the machine as it stands stationary. It is a picture, and similar to a picture, its threefold aspects require a human interpreter. Start it, go away, and the machine will function with or without you. In functioning, the hidden forces which the interpreter visualizes from the stationary machine become real; the conflict of parts in motion produces an all too evident wear and tear.

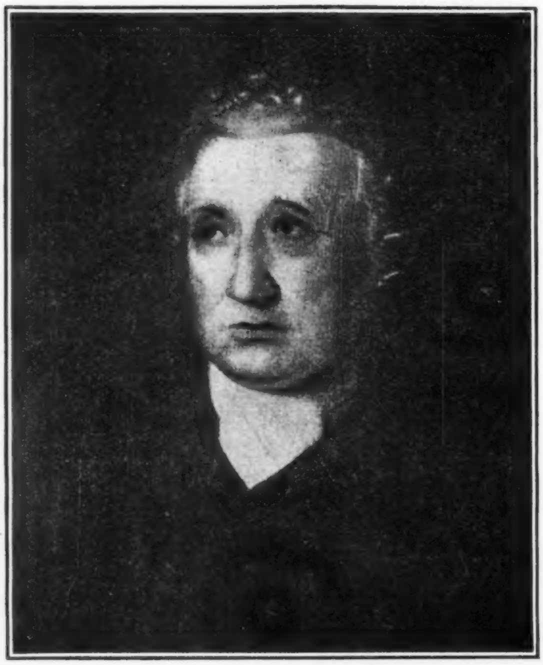
As for the third aspect of the visualization, that of the effect on the human race, no interpreter is at all necessary. With or without the cognizance of its subjects, the machine acting through its economic laws forces us to change our very lives in accord with its dictates.

As we trace the development of an invention we shall see that the invention passes through several stages which are common to all art. While passing through these various stages it will be found hard to distinguish the final objective. The machine designer may drop his pen and leave the machine in picture form, perchance to grace the wood engraving of a magazine. So far it has been merely that same form of expression that one finds among draftsmen and painters, and only according to the rules of the latter should it be judged. It is not by any means a machine; merely the picture of a machine, and the threefold aspect of the visualization still requires the human interpreter. Inherent in this expression so far are only those forms that one finds in any drawing.

In order to see more closely the sequence of the processes involved in the art of inventing, let us first consider the steps met in the general case, and later relate some specific examples. First, there is the idea. It originates in one man's mind. Whence its inspiration? Whence the inspiration for the conception of a great painting? Whence the plot of a novel? Whence the idea underlying any of the forms of artistic expression? They appear to come from all sources, but most frequently come from the doings of man, and principally from the failure to achieve an

[1] Vice-President, Brillo Mfg. Co. Mem. A.S.M.E.

From an address before The Andiron Club of New York City, October 12, 1927.



JOHN WILKINSON (1728–1808)
(*From "English and American Tool Builders," J. W. Roe. McGraw-Hill Book Co.*)

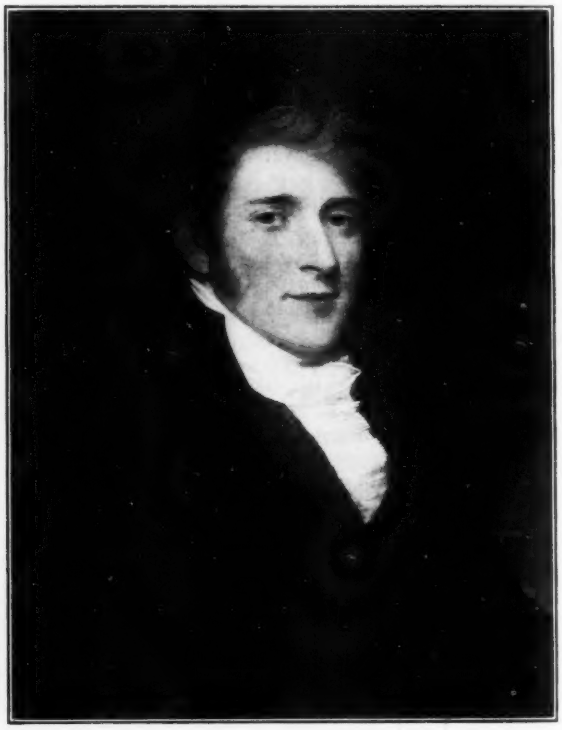
Inventor and ironmaster, whose boring machine was used in making Watt's steam engine and without which the engine had previously been a failure. Wilkinson launched the first iron vessel in 1787, and built the first iron bridge in 1779.

MICHAEL FARADAY (1791–1867)

As a journeyman bookbinder he was inspired by a lecture by Sir Humphrey Davy to enter the field of science, in which he laid the foundations of the commercial generation of electrical energy.

ideal in those doings. Out of this arises the need for the presentation of something more nearly perfect.

Thus, we find that the inspiration for the concept of a mechanical invention is the lack of perfection of fulfilment of man's needs by the mechanical world of the day. The first test, therefore, of an inventor, is the ascertaining of the need for an invention, and right here is where we have a very complete analogy to the usual types of artist. Many are the paintings which do not meet the popular taste of the day, and the following of such inspiration is the reason for the attic artist. If he follow this through to the bitter end and fail absolutely to fulfil the need of any patron, he steps from the attic to the gutter. Thus, the mechanical invention that fails to fulfil the need of the present commercial day follows the same course, and the inventor speedily finds himself in the gutter, perhaps more rapidly, for mechanical invention requires what is perhaps the greatest outlay of money in its prosecution.



ROBERT FULTON (1765–1815)

This portrait of himself by Robert Fulton, the inventor of the steamboat, hangs in the rooms of The American Society of Mechanical Engineers, to whom it was presented by Mrs. R. Anna Cary. Fulton abandoned painting, which he studied under Benjamin West, to devote his genius to engineering.

It is in this search for the idea that the inventor must differ largely from his fellow-artists. The ideas of most of our painters and writers are acquired from happenings of the past. These artists are the historians of the brush or pen. Their faculty of expression, of constructive imagination, lies in the method of presenting the facts of the past in their appeal to the eyes of the present with a hope for the future. Our inventor, on the other hand, is entirely of the future. All that is present is the need that should be fulfilled.

This difference in time is accentuated in its effect on the development of the art of inventing by the fact that time intervals are of themselves very important. The need is there; if our inventor does not fulfil it, some one else will. Consequently the development must be undertaken, and the art of the expression

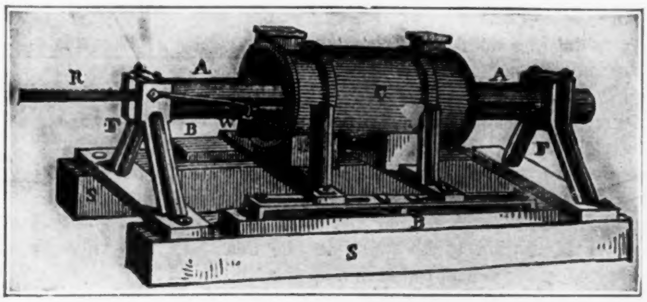
must make due allowance for the fact of haste. Some inventions take twenty or forty years to develop, but our inventor must take care that if he spends twenty or forty years upon his work of art no one else can develop it in half that time, else his development will never be completed. The interrelation between the inventor and his prospective purchasers is so intimate that each reacts upon the other in a manner not normal to the usual forms of expression, save perhaps in the theater, where the reaction of the audience upon the actor and, standing behind him, the composer or author, is well known.

A Newcomen Engine, Invented by Thomas Newcomen (1663–1729)

This historic relic gives an idea of the strange appearance of the prototype of the steam engine, the Newcomen engine, which was used for pumping water from mines. In working upon a model of this type of engine James Watt conceived the essential improvements which increased its economy and made it applicable to other uses than pumping water. The illustration shows the wooden walking beam by which the power generated by the downward movement of the steam piston on the left was transferred to the pumping cylinder on the right.

Assuming, therefore, that our inventor has an idea which, if developed, would result in a more nearly perfect mechanical operation, and further assuming that he has some means of livelihood to permit him to engage in the art of inventing, he starts by day-dreaming. The next implements to be applied are the pencil, paper, and, most important of all, the eraser. There are probably artists who paint without first sketching and resketching. I do not know them, but my acquaintance among artists is limited. There are probably writers who never foul a sheet by erasure, but again I do not know them, and again my acquaintance among writers is limited. I have, however, quite an acquaintance among inventors, and I assure you that the gradual putting on paper of the intangible idea of an inventor is a slow and laborious process, largely one of cut and try. Eventually, however, the design is completed. In its completion we note for the first time, however, quite a variation from the work of the normal artist. In commercial inventing today the main outline only is the work of the inventor. The innumerable details, of which there may be many thousands or hundreds of thousands, are most frequently filled in by assistants. To preserve the unity of concept throughout, the coherence of functioning of the finished machine, and yet to permit some individuality in detail, requires a technique not only of invention, but of science, engineering, and practical psychology, which we may define as management, not normally to be found in the other forms of artistry.

At last the drawings are complete, and another class of skilled workmen, and very highly skilled workmen they are, appear. This is the class of the toolmaker, and sometimes still another class, the patternmaker. They, themselves, have no part in the final machine, but they make from the drawings the patterns, forms, tools, and other fixtures, which are finally to constrain the skeleton idea, and to fashion around it the various materials. After this work is completed then follows the actual building of the machine itself. This machine may be of the nature of a small mechanism, so small that it requires a microscope to see it function, or it may be a machine the size of a large factory, weighing thousands of tons, and requiring the power of 50,000 horses to drive it. As the idea begins to formulate itself in this final form the inventor must be everywhere, for this is indeed the critical phase. This is the last chance to compare the reality with his vision, to probe for those elements of weakness which the mind's eye, intent on the broad outlines, failed to anticipate. It is still, however, the building up of a stationary picture; the human interpreter is still required to complete the vision, and to prophesy the movement that is to be the very life of the machine. In addition, there now enter those dangers from without, which tend to prevent the consummation of the achievement, and which are in no way due to the inventor himself or deficiency in his work. Chiefest among these are defects in materials, either faulty on account of their origin, or because of lack of sufficiently severe limits in their specifications. Next comes intentional or careless deficiency in workmanship. Both these hazards can be overcome only by the constant use of the inventor's "all-seeing eye;" he must be the chief inspector, and what is even more important, he must have and hold the complete and enthusiastic support of all the workmen. In order to accomplish this he must be a real leader—he must imbue the leaders among the hundreds of workmen with enthusiasm for the concept, and make each feel an interest in it second only to his own. In order to accomplish this he must be a real leader of men, and at times a great diplomat, for not only are the natural feelings of men to be overcome, but also he can never lose sight of the fact that the skilled workman looks upon



Wilkinson's Boring Machine, 1774

(From "English and American Tool Builders," J. W. Roe. McGraw-Hill Book Co.)

Watt's first engine was a failure because of the inaccuracy of the Smeaton boring machine at the Carron Iron Works. In 1774 John Wilkinson invented an improved boring machine with a heavier boring bar supported at both ends. In 1776 Mathew Boulton, Watt's partner, wrote: "Mr. Wilkinson has bored us several cylinders almost without error; that of 50 inches diameter, which we set up at Tipton, does not err the thickness of an old shilling in any part."

the machine as an instrument of torture to degrade his fellow-workmen and the result of it, when once built, will be to extinguish the livelihood of many of his fellow-workers. Then again as the work progresses it may be found that the normal art of machine fabrication is not equal to the task, and new developments in other arts must be incited and nourished to completion by the inventor. Finally, the machine stands before you, a finished piece of work. How does it differ as it stands from the other forms of expression which are recognized today?

Compared with the wielders of the pen or brush it is only a further step in visualization. It had to pass more or less skilfully through those phases represented by the book or canvas. Its success, however, is not a matter of judgment at the time of its embryonic appearance in the forms above mentioned, but must stand finally as the complete machine, and only then, after it has acquired the life of motion, and functioned as planned. In the first respect it may perchance be more nearly likened to a product of the art of sculpture, but because of the magnitudes involved, the average invention is more similar to that kind of sculpture which involves carving the side of a mountain.

And now we come to one function of art that mechanical invention alone has to conquer. All other forms of art, excluding perchance only drama in both forms, the spoken and the moving picture, are stationary. The most thrilling painting of the charge of horsemen, strange to say, can represent action only by taking the bodies at the moment of rest, a curious psychological but nevertheless true axiom. In addition the paintings themselves are stationary, and books must needs be stationary, but a machine does not fulfil its concept until it is in motion. The more refined the art, the greater the so-called poetry of motion to be found in the machine. Take a well-designed machine and put it in a shop window and let it operate. A crowd at once is attracted. Stop it—the crowd disappears instantly. The attractiveness of a machine is its movement. The attractiveness of any other form of art lies in its stationary features.

I no sooner have said this than I must acknowledge a tremendous exception. A form of art that an engineer is ne'er supposed to know, relies upon motion for its effect, but whether the effect itself is static or dynamic I do not know. I refer of course to music, for it is by thousands of vibrations that the pleasurable sensations are revealed. The music is of itself action, and a great inspiration to action, and strange to say, the machine that moves borrows its ideas of harmonics from the art of music.

Because of this requirement for motion a secondary element that is most important enters into machine design, which normally can be left unimportant in the other arts: that is, the nature of the materials that must be utilized. (Paper, typewriter, ink, vegetable or mineral paints, and other mixings, are subjects of vital interest to the artist and author, but rarely do the weight and strength of the materials, and still more rarely does the life of such materials, cause any worry or concern.) The strength and weight of materials are of the essence, as the legal mind would say, in mechanical invention. In other words weight, strength, resistance to corrosion, to impact, to fatigue, to stresses of all kinds, real or imaginary, to the circumstance of collision, of breakage, of wear and tear, of contaminated atmosphere, of escape of heat, of capture of light, ability to convey vibrations of all kinds, the control of energy thereby, and many other properties, must all be considered by the inventor. It is here for the first time that engineering and chemistry become the true allies of the inventor, and he reciprocates by forcing his allies to produce for him that which they have not before produced. It is a strange fact that every great invention has caused to be developed with it a new material, and every new material has in turn created a number of other inventions, thus creating an endless chain.

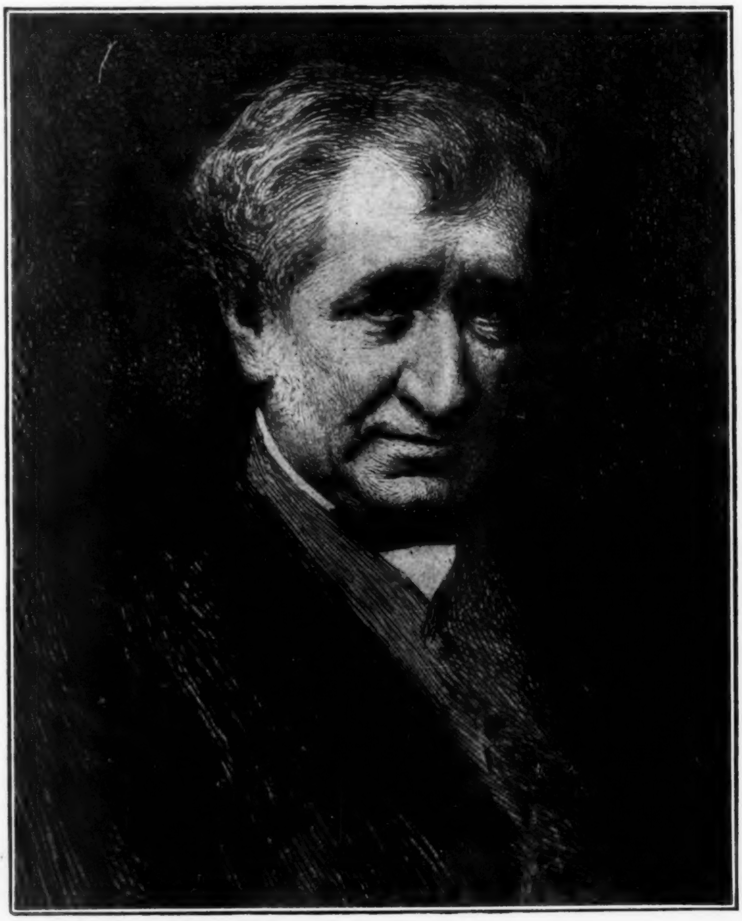
ELI WHITNEY (1765–1825)
(From "English and American Tool Builders," J.W. Roe. McGraw-Hill Book Co.)
Inventor of the cotton gin. He introduced the system of interchangeable manufacture which has been a powerful factor in the supremacy of American industry.

It is true that inventors are classified into specialists like other types of artists. Thus we have the artist who paints miniatures, or large canvases, and the engineer who prefers to work with small things like watches and sewing machines, and the engineer who designs a huge furnace or rolling mill. When one follows the profession of mechanical invention, however, he is likely to jump from one specialty to the other. Thus, I know of a man whose one invention had to do with harnessing forces of nature displayed most frequently at needle points, and who followed almost immediately with an invention that weighed a thousand tons and required the power of 500 horses to operate it. The elder Brunel's first inventions were machines for making shoes for soldiers of Napoleonic wars, but he was knighted for his tunnel under the Thames.

One curiosity of inventors as a class is that they frequently have utilized other forms of artistic expression simultaneously with their work. Thus, for example, we have the well-known Robert Fulton, painter of miniatures, inventing a steamboat, and it is hard today to tell whether one of our present-day recognized inventors is better known for being a musician or an inventor; or may we add, a socialist?

When it comes to the daily work of an inventor, he may be compared with an explorer. The same qualities are required—the piercing into the unknown, the inspiration to followers, the resourcefulness at each step, the conquering of nature in her violent moods, all making them brothers-in-arms. Two qualities they must have in common, courage and energy—courage to follow the trail to its end, and then, beyond, courage to meet all comers, materials, forces, age, fatigue, persons; and energy to eliminate them as obstacles from the pathway. Energy is indeed essential, and owes its high position in the inventor's make-up to his handicap of time; were time not an essential in the development of an invention, then courage alone might suffice.

As the mind rambles along in a search after specific examples of the rather broad generalizations just formulated, it naturally gravitates back to the one who really started the great wave of mechanical invention that has already lasted 150 years. His invention passed through all the vicissitudes of its countless successors, and his methods varied but little from those used today and ever since by the inventor. Very hastily, therefore, let us touch upon the invention of the application of mechanical power to industry, the steam engine of James Watt.



JAMES NASMYTH (1808–1890)
(From "English and American Tool Builders," J. W. Roe. McGraw-Hill Book Co.)
Inventor, engineer, artist, writer, astronomer, archeologist, from whose autobiography this and other illustrations relating to him are taken. He was the youngest son of Alexander Nasmyth, "father of Scottish landscape art."

Watt was an instrument maker in a college at Glasgow. One day a professor gave Watt a classroom model of Newcomen's engine to repair. This he soon did, but the job started him thinking.

The Newcomen engine was a well-accepted tool of the mining industry. For over 50 years (as the first had been installed in 1711) it had been fulfilling its task very well indeed, and practically all the mines of Britain were dependent upon it. It was called a steam engine; today we should call it a steam pump, but in those days the application of steam to anything but pumping was not considered.

Watt began to study carefully the Newcomen engine, especially its imperfections. In a series of steps, including the use of a separate condenser, a jacket to keep the cylinder warm, covering the cylinder with a head so that steam could be used on either side of the piston, and many details, he made sketches and illustrated their application by making small models to demonstrate these various points, but had not the resources to make a large engine.

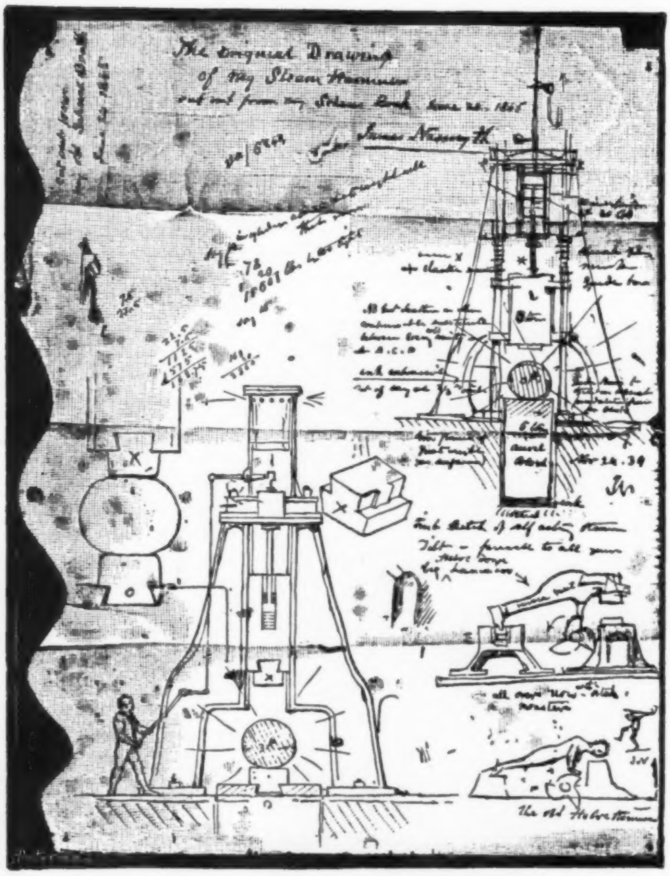
He followed the course of many a poor artist in the hunt for a Maecenas, and finally persuaded John Roebuck, proprietor of the Carron Iron Works, to play that role. Then came the draftsmen, pattern-makers, and mechanics, and the construction of the first steam engine began. Watt followed all the precautions I have mentioned while the work was in this critical stage, but nevertheless failure ensued, and in the failure the good Samaritan Roebuck crashed to ruin, and carried his whole company into bankruptcy.

The creditors now stepped in, and being typical business men, didn't consider Watt's invention worth a farthing, so they allowed him to retain his rights, in order the more easily to get rid of him. And so all work on the steam engine ceased, and Watt returned to abject poverty for many years. In his wanderings he happened upon Matthew Boulton, a wealthy, strong-minded business man, with great courage and vision. Soon the famous firm of Boulton & Watt was formed, and again the engine was started. After many failures, success was finally accomplished.

But why did the first engines fail, even though the models worked, and how was success finally attained?

It is the old, old story of an invention which is just beyond the capacity of the developed materials and craftsmanship of its time, and forcing their development, often having to wait for it. This effect is difficult to anticipate prior to the building of the first full-size machine, and is one of the important causes which make that phase of the development of an invention so critical. In Watt's time, small cylinders of model size could readily be made, but when it came to full-size engines nobody could bore a big hole at all accurately. Watt frantically sought, Boulton prayerfully worried, all the unknowing world waited, till a man who could bore a hole should appear.

After seemingly exhausting the arts of peace, Watt turned to



Original Drawing of the Steam Hammer from Nasmyth's "Scheme Book," November 24, 1839

The original steam hammer, built by French engineers who had been shown this drawing at Nasmyth's works, was first seen by the inventor in operation in 1842 at the works of Schneider, Le Creusot, France, where, upon inquiring how a large crankshaft had been made, he received the astonishing reply, "It was forged by your steam hammer!" Nasmyth, previously unable to get money to patent this invention, but extremely liberal in permitting visitors to see his original designs in the "Scheme Book," hastened to patent the steam hammer in order to secure for himself the benefits of his idea.

the War-God. And as usual the latter was not found wanting, and produced the man, John Wilkinson, cannon maker to the British Government. In order to make cannon he had devised a machine which bored them more accurately than was ever possible before, and the application of his method and machine solved Watt's problem. The first engine was finished and put into successful operation, to be followed by many others, and the great prosperity of the firm of Boulton & Watt.

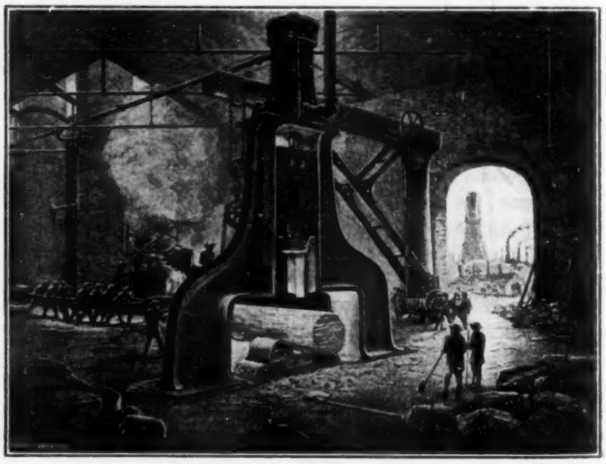
Watt continued to invent and improve his engines, and was followed by numerous other engine inventors. He applied his engines first to the textile industry, which rendered possible the extended use of the great inventions of Arkwright, Cartwright, Crompton, Whitney, and many others, and this movement soon took manufacture out of the home to establish the "factory system." Thence it spread to all forms of industry, including not only manufacture, but also mining, agriculture, and transportation. In looking back it becomes extremely difficult to differentiate the third aspect of the visualization of Watt's first steam engine from that of his following engines, and from those of other inventors, so closely do all third aspects blend together in time.

We have seen how in Watt's case his success was due to the success of another's invention. This appears to be true in most inventions, and even in those cases where an invention fails in its technical or commercial development, it still may prove the salvation of another's. This latter fact was brought home to me in considering a scene in a British shipyard of long ago. A young ship designer, Brunel by name, the son of a famous engineer inventor, was conversing with another inventor, a relative of mine. Brunel was all enthused; before him lay his masterpiece, the largest steamship ever built, and one which was destined not to be surpassed in size until comparatively recently. His friend's project of a cable between Britain and America was still in the land of dreams. Nevertheless, after many failures, the salvation of his dream was the *Great Eastern*, a technical success but a commercial failure, which was turned over to Field for his cable because its huge size prevented its commercial use at that time. Yet it was this huge size that made it alone the only ship which could lay the cable —which it succeeded in doing.

From these examples it will be seen that the art of invention has the very technical phases clearly defined, but the inventor must also take care to be skilled at least to a small degree in those accompanying arts without which he cannot exist. Primary among these is the art of protection of his idea, both from a commercial and from a legal viewpoint. It is curious that although I have emphasized throughout the concreteness and reality of the machine, yet it is true that the invention itself is the most abstract of all creations. Its existence in fact is purely a legal fiction. The machine, which is the expression of the inventor, is not itself the invention. The invention is the result of the art of legal definition by the patent office of the results of this form of an expression of the creative instinct by an individual, and exists only in so far as it is decreed by the regulations and decisions of the patent office and the substantiating courts standing behind the patent office.

Having thus described certain steps in development, or the process of the art of expression as applied to a mechanical invention, at once the thought arises that as it becomes more and more standardized an art, then a group of men may perchance invent. This theory is lived up to very much by certain of our large corporations that have endowed research laboratories upon which they count for the issuance of all of their so-called inventions.

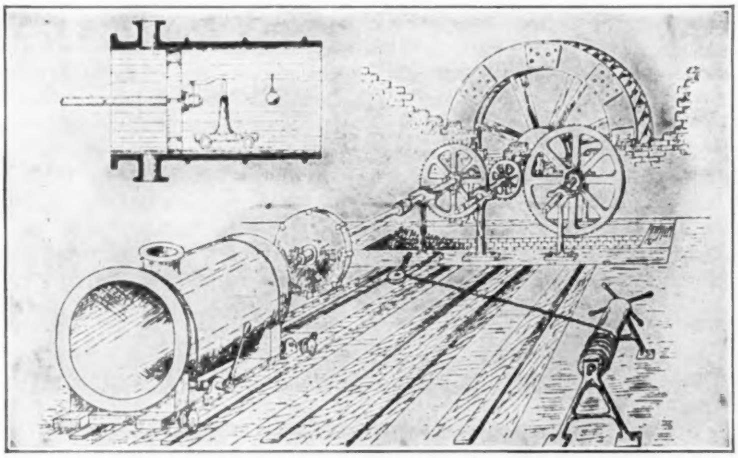
The fallacy in this lies in the fact that inventing is an art,



Nasmyth's Steam Hammer at Work

This illustration is reproduced from a painting by the inventor, and is offered as evidence of his ability at expression in other forms than those of mechanical invention.

and is not a handicraft. A true inventor must have mental freedom, and it is only in free minds that a real invention is born. Such a mind is abhorrent to any form of organization, for the sole function of an organization is to limit freedom of activity. To be sure, once the real invention has been born, then a horde of research men may engineer minor developments which may of themselves be of great value to the company, but it is hard to consider such modifications of the expression as true creations. Now and then a real inventor will be found in such a laboratory, but he exists in spite of the laboratory, not because of it. The great difference between the art of invention, and the oft mistaken arts of engineering, of research, of scientific exploration, is quite definite, but one not normally understood. There is a dash of the intuitive, an inspiration that flies in the face of known facts, a boldness of outline on the canvas of the tomorrow, ever present in the inventor, and essential to the practice of his art, which are never found in the cold, logical group mind necessarily allowed in an administrator. It is in this fact that we have the great hope for the future; otherwise with the consolidation of the tremendous financial resources provided by the great clustering together of many, coupled with the possibility of united direction of such a countless number of men, there would soon be concentrated into one great corporation substantially the entire industrial output of a nation, even perchance of the world. There are many economic forces preventing the expansion to too great a degree of such an octopus, but by no means least among these compulsive forces is the individual inventor who may, perchance, with a single idea, cause a large corporation to wither into nothing.



SMEATON'S BORING MACHINE, CARRON IRON WORKS, 1769

(From "English and American Tool Builders," J. W. Roe. McGraw-Hill Book Co.)

The impossibility of securing accurate work with an overhung cutting tool on such a long, light shaft foiled Watt's early attempts to bore engine cylinders and resulted in the financial ruin of Watt's backer, John Roebuck.

In so far as an invention is purely imitating the motions of a human being by mechanical movements, the hack engineering mind may suffice. Real inventions are rarely made that way. What is required is the analysis of the individual results of these motions at critical stages in their functioning, and the creation of simple mechanical means to produce these same results.

I have tried to show that there is an art of mechanical invention, and that this art differs from both engineering and mechanics and is truly one of the several forms of expression of the creative imagination; the other forms have been recognized as art. The sources of inspiration are similar, there is an established technique of development very like the technique of development of the other forms and, in fact, identical with some of the other forms in its early stages. The principal difference is in size and the concept of movement of its parts, and the results thereof. All art is visualization of an idea; this visualization partakes of a threefold nature. First, the art must denote something specific, a given shape. Next it must by connotation bring forth visions not specifically denoted. And, finally, the visualization must be the producer of another vision—the effect of the work upon the race. Works of art other than mechanical invention require the human interpreter throughout; a mechanical invention once perfected will cause the laws of nature to realize all three aspects of the visualization without further presence of the interpreter. These generalizations have been discussed in greater detail, and methods and examples of the developed technique or art of invention have been mentioned.

Writers on religion, philosophy, and economics and other worthy fellow-artists have been struggling for centuries with the problems of acclimating man to his environment with the utmost happiness. We need them. They have all done great and noble work, but I can make huge claims for the benefits of the mechanical invention as a form of expression, as made for us in our social and economic life. The workers have come up from huts and serfdom. Human slavery has been abolished almost everywhere, and these things have been done principally because of the inventor, followed by his allies, the engineers and the chemists. The reason that the slave is no longer to be found in all countries is not an abstract law against slavery, but the fact that the iron slaves of countless inventors now stand ready to do your bidding. A free man in the old days was indeed wealthy if he had more than two or three slaves. Today every one of us utilizes thirty. In those countries where the effects of mechanical invention have not been felt the slave ship still travels, and the cessation of slavery cannot be accomplished by guns. It can be accomplished only by the substitution of the iron slave.

Diesel Engines in Motor Vehicles

EXHAUSTIVE experiments on the test block have given a rather clear idea of the suitability and efficiency of engines of the Diesel heavy-oil type for motor-car propulsion, writes Dr. Wilhelm Riehm, of the M.A.N. engine works in Germany, in the May issue of the *S.A.E. Journal.*

Application of the four-cylinder engine up to the present has been mainly on 5-ton trucks operated generally with a 5-ton trailer. Confirmation of the fuel economy found by experiment on the test stand was secured under operating conditions by comparative tests with carburetor engines of the same power installed in trucks of the same type. According to these tests, the fuel consumption of the Diesel engine is 64 per cent of the consumption of a gasoline engine, in round numbers. The saving in running expenses is considerably higher than this indicates, depending on the relative prices of the fuels.

The favorable running qualities of the Diesel-powered car have been confirmed fully in practice; indeed, the Diesel engine materially excels the gasoline engine in flexibility. Varying rolling resistance is overcome easily by the Diesel engine, because of its increasing pulling power with decreasing speed.

Experience obtained with about 100 trucks thus far put into actual service with M.A.N. engines indicates that they have met fully the requirements of running and traffic and leaves no doubt that the Diesel engine is the equal of the highly developed carburetor engine in reliability.

Fuel Handling and Ash Disposal

Methods and Equipment Used on the Philadelphia Electric Company System

By J. R. McCausland,[1] Philadelphia, Pa.

A discussion of the methods and equipment used for handling fuel and ash on the Philadelphia Electric Company System is best considered by a general outline of the factors which govern the selection of the equipment.

The fuel used on the system is bituminous coal secured from the Pennsylvania region embracing Indiana, Clearfield, and Cambria counties. This region is served by two railroad systems, both of which have excellent terminal facilities on the Delaware River in Philadelphia. These systems are the Pennsylvania and the combined New York Central and Philadelphia and Reading. The tidewater terminals of both of these systems embrace large yards for the accumulation and classification of coal, thawing sheds, and car dumpers. As an inducement to use these facilities and also to insure the prompt release of their rolling stock, both systems allow a differential of twenty-five cents per ton over car delivery to the individual plants.

Shipping Conditions

In consideration of the foregoing and also since the generating stations are located on the Delaware and Schuylkill Rivers in close proximity to the terminals noted above, some form of equipment capable of unloading river craft was selected. In both rivers we have splendid harbor conditions, free of congested shipping and bridge obstructions and seldom subjected to protracted ice conditions. It is usually possible to make delivery to all stations on the tide. The type of river craft used are flat-bottom, box-type barges which vary in length from 100 to 150 ft. and in width from 30 to 40 ft. and draw approximately 17 ft. of water when loaded. The barges transport from 900 to 2200 tons of coal per trip, depending on their size. These barges and tugs with the exception of two boats are not the property of the company, but are contracted for on the cost-per-ton basis of transporting. For obvious reasons, the author believes that as long as reasonable rates can be obtained, it is not advisable for the company to own or operate this type of equipment.

However, in the design of coal towers it was necessary not only to keep in mind the type of equipment mentioned heretofore, but also to bear in mind the ocean-going barges which transport the coal from the non-union mines of West Virginia, during strikes or suspensions in the coal fields of Pennsylvania, or during railroad difficulties.

The coal is shipped in these barges from Norfolk, around the Capes to the Delaware breakwater, and thence up the Delaware River. This type of barge averages in length from 200 to 400 ft. with a 40-ft. beam, and draws when loaded approximately 22 ft. of water. They have a carrying capacity of from 1000 to 3000 tons of coal. In most cases the company's docks are only good for 17 ft. of water at low tide, so it has always been necessary when using this type of barge to spot on the high water and endeavor to lighten the cargo before the dropping of the tide. In unloading ocean barges, it is necessary to use a number of men for trimming, thus materially increasing the unloading cost per ton over normal practice of unloading from the river type of equipment.

Aside from the study giving the factors mentioned heretofore, other features considered are the initial cost of equipment, economy of operation, and unloading requirements. From the foregoing it is readily seen that the necessity of providing local facilities for rapidly unloading large numbers of railroad cars at the various plants is eliminated, and with it goes the necessity of having large storage yards, car dumps, skip hoists, and like equipment, permitting a concentration on equipment best suited to local needs and conforming with conditions as presented. Before proceeding, however, it might be well to state that railroad facilities in the various plants have not been entirely neglected, as small track hoppers adjacent to our piers and docks have been provided. The hoppers are equipped with portable belts for transferring the coal from the bottom of the cars to the barges, after which it is elevated in the towers. In locations where track hoppers have not been provided, the locomotive cranes are used for transferring the coal from the cars to the barges. The capacity is limited by this method, however, to approximately 150 tons per hour.

Unloading Equipment

The equipment for putting coal into the bunkers starts in all cases with the coal unloading towers. The limiting factor in the design of the towers is the height of the boom above the water in order to clear the masts of the ocean-going barges previously mentioned. This type of equipment is provided with masts standing from 40 to 50 ft. above the high water. It is, of course, out of the question to attempt to unload steamers under the towers. To unload from steamers it would be necessary to transfer the cargo in midstream to barges. However, if necessary the facilities at Petty's Island could be enlarged to accommodate steamers. This island is situated in the middle of the Delaware River very nearly opposite the Delaware plant, and is utilized for storage of coal.

The coal towers are essentially of the grab-bucket type, controlled by a double-drum hoist. The leads operate over a trolley running on a horizontal boom which projects out over the barge which is to be unloaded. A special drum controls the movement of the trolley, with one man controlling the entire operation. This grab-bucket system is a hoist and does not attempt to transport the coal as do other grab-bucket systems.

The towers at Chester and Richmond Stations (Figs. 1 and 3) are of the hammer-head type, while those at the Delaware (Fig. 2), Petty's Island, and Schuylkill plants are of the steeple type. These names are derived from the construction of the members supporting the boom and cable sheaves, and the selection was influenced by the architectural design of the plants. In all but one plant the coal-tower booms are an average of 90 ft. above high water, Chester plant being the exception where the boom is 160 ft. above high water. In so far as the operation is concerned, the lower towers are preferable as they are easier to operate, the boat is more readily seen through fog or smoke, night operation when required is simplified, and the bucket is more readily controlled during adverse weather conditions.

In considering capacity, speed, etc. for a given tonnage, the size of the barge hatchway determines the maximum size of the grab buckets, regardless of all other factors. To safeguard operation, each tower must have sufficient capacity to handle the maximum daily hoist. The towers are installed in duplicate so that in the event of failure of one, the other can be thrown into

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[1] Supt. Coal Bureau and Steam Heating System, Philadelphia Electric Company.

Presented at the First National Meeting of the A.S.M.E. Materials Handling Division, Philadelphia, Pa., April 23 and 24, 1928.

service. This precaution also facilitates the handling of barges, as loaded barges can be moored while another barge is being discharged. In all but one case the towers are housed in the same structure on a pier extending into the river, and arranged so that they operate on opposite sides. At the Chester plant the towers are on opposite sides and project over the inshore basins.

The practice has been to construct fixed towers because it is more economical by far to move the boat than to move the towers; and the fact that it is a hoist system only and that it is tied in with the delivery systems from the coal wharf to the coal bunkers practically fixes this point of construction.

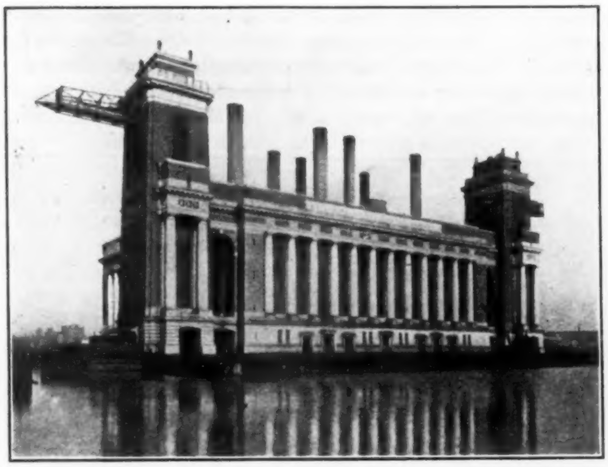

Fig. 1 Chester Station

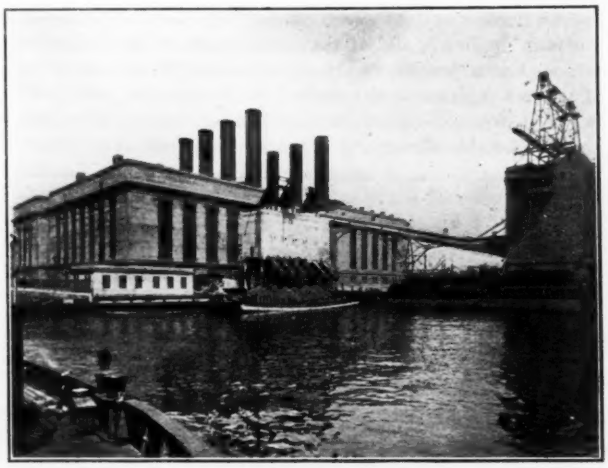

Fig. 2 Delaware Station

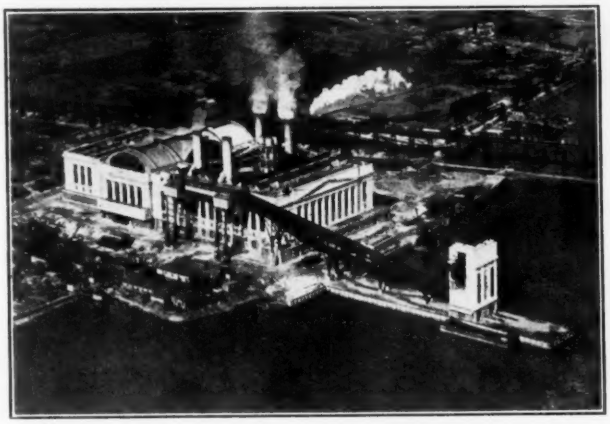

Fig. 3 Richmond Station

The selection of equipment for a distribution system is one which is largely governed by the amount of space available at the plant, this being responsible for the radical change in design between the Chester plant and the Richmond and Delaware plants.

Description of Individual Plants

The oldest plant on our system is Schuylkill No. 1 and is located on the Schuylkill River. The coal is unloaded with two steeple-type towers, one electrically operated and the other steam driven. These towers were operated formerly by two men, but were later reconstructed for one-man operation. At this plant the coal travels from the receiving hopper through a single-roll crusher to cable cars, which are drawn up an incline approximately 800 ft. long and discharged on secondary hoppers. From these the coal is discharged through double-roll crushers and then elevated to the top of the plant by pivoted bucket elevators and distributed over the bunkers by flight conveyors.

The Schuylkill No. 2 plant was constructed in later years directly in back of the No. 1 plant. This merely called for an extension of the cable-road system and a similar installation of bucket elevators and flight conveyors. Coal is weighed by standard beam scales on the loading platform.

The Chester plant was constructed very close to the pierhead line with the thought of possible development of another plant in the rear of the present one, thus eliminating the use of an incline bridge for inclosing a transverse-belt system. At this station the coal is unloaded by hammer-head-type towers as mentioned heretofore, and from the receiving hopper passes over a small iron apron to double-roll crushers, from whence it goes to the cable-road floor. It is then fed into cable cars through manually operated, double cut-off gates on the loading hopper above the cars. Cable cars rest on the platform scales while being loaded, and when a predetermined weight of coal has been fed, a signal light flashes and the gates are closed. The cars then distribute the coal direct to the bunkers.

In the Schuylkill and Chester plants, very large coal bunkers have been constructed above the boilers, capable of carrying three days' supply of coal. In the construction of the Delaware and Richmond plants the policy of having large bunkers was discontinued for several reasons as it was found hard to substantiate the initial cost of investment for carrying the buildings to sufficient height to house such large bunkers, and on the other hand it was found that the bunkers were more of a detriment than an asset, inasmuch as it was necessary to clean them out periodically to prevent fires. Further the design and construction of the boiler rooms in the more recent plants did not lend themselves readily to the construction of large bunkers. In the newer plants the bunker capacity is good for approximately twenty-four hours' supply.

At Delaware and Richmond stations the towers were constructed on piers, and ample space was available for the construction of belt conveying systems. As the design is similar in both stations, a description of the coal-handling plant of our Richmond station will answer for both.

The coal is distributed from receiving hoppers on a short apron feeder, from which it feeds over a rotating grizzly. The grizzly is equipped with a series of multiple disks set for $1^1/_4$-in. screenings. The "fines" are diverted to a chute by which they by-pass the crusher and feed to the hopper over the main incline belts.

The "overs" discharge on a 42-in. picking table so arranged that foreign matter such as tramp iron, wood, etc. is easily removed. From the picking table the coal goes through a double-roll crusher set for $1^1/_4$-in. lumps and falls to the hopper over the main incline belts. At this point water sprays have been installed to spray the coal if it is very dry and dusty. The incline belts are 36 in. wide, are of eight-ply construction running over the latest type of anti-friction carriers, and operate on a 20 per cent incline. The main incline belts discharge to transfer belts and thence to the bunker belts where the coal is diverted to the desired bunker by movable trippers. The installation throughout is in duplicate, and at the exchange points the hoppers are arranged with flop gates so that the coal can be carried on either of the two systems or any desired combination of them. Each belt system was designed to carry 365 net tons per hour, but is actually capable of carrying 410 tons as determined by test.

Automatic motor-driven coal samplers are installed and a continuous sample is taken of the coal fed to the belts. These samplers are installed at all stations and fill a very important function, as the coal is purchased on a B.t.u. penalty-bonus basis The amount of coal carried to the bunkers is determined by means of "weightometers" which automatically record the weight of coal passing over them. This affords a check on the bill of lading and also gives a record of the coal handled.

There are several interesting auxiliary features in connection with the belt systems. The main incline belts are housed in a bridge-type structure which is divided in half throughout its length by a firewall separating the two belts. There are fire partitions at each end and in the middle, to minimize the danger of dust explosion and fires. A bell code is used between the operators. The belt systems are installed with interlocking relays so that the system can only be started from the bunkers back to the tower, and that when the coal is started it can meet only moving equipment. The failure of any unit immediately trips out and stops all the units in back of it. This serves a dual purpose: first, it permits the use of only three men to run the entire system, a hoisting engineer, a picking table man and a bunker man; secondly, it prevents spilling of coal and choking of hoppers due to equipment failure or human error. Quick-stop buttons are provided for emergency use. As an additional precaution a device has been installed for tripping out the system, if for any reason the hoppers at the main exchange points choke up.

FIG. 4 CATERPILLAR TRACTOR PACKING COAL AT PETTY'S ISLAND

FIG. 5 REMOVAL OF STOCK COAL AT PETTY'S ISLAND

TABLE 1 GENERAL DATA, PHILADELPHIA ELECTRIC COMPANY COAL- AND ASH-HANDLING PLANTS

	Richmond	Delaware	Chester
Coal Towers	2	2	2
Height of boom, ft	93	87	165
Operating Cycle			
Closing bucket, sec	3.3	1.2	4.1
Hoist and trolley (in), sec	5.8	6.0	12.2
Tower and trolley (out), sec	9.6	9.2	17.2
Complete cycle, sec	18.7	16.4	33.6
Rate on full boat, net tons per hour	371	365	199
Rate on half boat, net tons per hour	291	314	186
Rate, trimming, net tons per hour	197	206	163
Average rate, net tons per hour	269	283	170
Tower Motors			
Hoist	2—400-hp., 2200 volt	2—375-hp., 2400 volt	2—450-hp., 220 volt
Trolley	2—50-hp., 2200 volt	2—35-hp., 240 volt	2—20-hp., 220 volt
Barge	2—50-hp., 2200 volt	1—52-hp., 240 volt	2—50-hp., 220 volt
Buckets	2—$1^1/_2$-ton grab (cable)	2—$1^1/_4$-ton grab (chain and cable)	2—$1^1/_2$-ton grab (chain and cable)
Cable Life (avg.), long tons	180,000	200,000	80,000
Crushers	2—36″ × 48″ double roll	2—36″ × 48″ double roll	2—28″ × 36″ double roll
Motor	2—50-hp., 2200 volt	2—75-hp., 240 volt	2—30-hp., 220 volt
Main Belts	2—36-in., 8-ply 968 ft. long	2—30-in., 6-ply 750 ft. long	Cable road having a $^3/_4$-in., 6 × 19 cable approx. 1400 ft. long with avg. of 12 3-ton cable cars.
Transverse Belts	2—36-in., 6-ply 251 ft. long	none	
Bunker Belts	2—36-in., 6-ply 613 ft. long	4—30-in., 6-ply 382 ft. long	....
Motors (transverse belts)			
Main Belts	2—50-hp., 2200 volt	2—40-hp., 240 volt	....
Transverse	2—$7^1/_2$-hp., 220 volt	....	....
Bunker	2—20-hp., 220 volt	4—20-hp., 240 volt	2—60-hp., 220 volt
General Costs			
Power per ton, mills	6.5	4	5.3
Labor per ton, cents	4	4	3.5
Maintenance per ton, cents	2.5	3	3

Locomotive cranes on system, 30-ton cranes, 60-foot booms.
Operating cost, labor and maintenance, $2.75 per hour.
Cost of handling coal or from stock, including labor and maintenance of machinery, 9 to 14 cents per ton.

ASH-HANDLING FACILITIES

At all stations, except Schuylkill and the old half of the Chester plant, the ash hoppers under the boilers are equipped with piston-type, air-operated, double-acting ash gates. The ashes are drawn

into rocker-bottom, side-dump cars of approximately two-cubic-yard capacity and hauled in trains by storage-battery locomotives to the pit or skip hoist. At Richmond and Chester there is a pit holding about three days' run, and at Delaware and Schuylkill a skip hoist is provided with overhead tanks of approximately two days' run. In connection with the ashpits locomotive cranes are used to transfer the ashes into railroad cars or on lighters.

Experience has shown that the pit-and-crane combination is the most desirable in that the investment cost is lower than that required for the skip-hoist construction, the maintenance cost is lower, and the operation as a whole is more flexible. This is not meant to imply that the skip hoist is an expensive piece of apparatus to operate, but it takes into consideration the extra investment required for special structural treatment to make the tanks and the building housing the skip hoist harmonize with the architectural features of the station, such as was necessary at the Delaware Station. This form of construction also partially obstructs the view of the station from the river front.

The ashes are ultimately disposed of by sale to outsiders or used in fills reclaiming the company's property. A ready market for the output of cinders has been found for about nine months of the year.

Coal Storage

In common with all other public utilities, the company must maintain a storage of coal to safeguard its operation against strikes at the mines and on the railroads, and for non-deliveries of any nature. The amount of storage is based on requirements for a period of time which experience indicates affords the necessary protection. It has been the practice to store emergency coal at all stations, usually carrying from two to three months' supply, but maintaining the bulk storage at Petty's Island. At this location are complete and independent facilities for handling 200 tons per hour on the average or 300 tons per hour for a short duration of time. The permanent layout consists essentially of two unloading towers, crushers and unloading hoppers for stocking coal, and two reclaiming hoppers, apron conveyors, and bucket elevators used in reclaiming coal. In connection with this equipment there is a boiler plant and a small turbo-generator as an insurance against failure of the submarine cable from Delaware station. The coal is stored and reclaimed by use of locomotive cranes, hopper cars, and yard locomotives. This equipment is used in preference to other systems because it lends itself much better to the storage method and also the investment cost for the tonnage handled is low. The locomotive crane is the very essence of mobile equipment, and with it the storage is not as restricted as with other systems The adoption of the locomotive crane is not entirely due, however, to its adaptability to the various coal-handling problems to which it is applied, but because it is a device which performs very well a variety of duties. With the locomotive cranes, the coal can be handled at a low labor rate. The method is very flexible and coal can be properly disposed in layers, which suits the method of storing to prevent spontaneous combustion. During the periods when the cranes are not being used for handling coal they are transferred to the construction and maintenance departments for their work, as often several years elapse before it is necessary to use the cranes for the storage or reclaiming of coal. By transferring the cranes to other lines of work, a large idle investment and consequent maintenance to prevent deterioration are avoided.

Prevention of Spontaneous Combustion

The method used for storing coal is based on the exclusion of air and the prevention of its circulation. It has been found that coal can be stored by this method for long periods without serious deterioration and absolutely without fires. The coal is placed in layers about 18-in. thick, and each layer is leveled and rolled in tight with caterpillar tractors. (See Fig. 4.) The piles are built to a height of 30 to 35 ft. by this method. Reference to Fig. 5 will show how successful this rolling is done by the straight wall of coal that is to be seen.

That the method is successful is shown by the fact that within the past four months approximately 100,000 tons of stored coal have been removed, and it shows an average B.t.u. loss of only 3 per cent on the dry basis, an average moisture gain of 2.5 per cent, and an average loss in volatile matter of 1 per cent. A large amount of this coal had been in storage for five years.

It is the practice to take temperature readings of all the stock piles at frequent intervals. A portable protectometer is used for taking temperatures. This instrument has a twenty-foot extension which is driven into the coal for its full depth. We have found that the temperature of freshly stored coal runs about 95 deg. fahr., but that there is a gradual falling off over a period of years, so that at the end of five years, for example, the temperature will range about 75 deg. fahr. in the center of a pile.

Comparative merits of other forms of equipment for handling storage coal have not been dealt with, as it is not felt that they are applicable to the company's needs. In the Philadelphia Electric Company System coal-handling operations are concentrated in the hands of the coal bureau, a section of the station operating division. The bureau is responsible for the coal from its source to the bunkers, regulating and classifying the shipments, dispatching barges, unloading the coal, and removing the ashes, in addition to the care of all docks and wharves in connection with the company's property. This fixes the responsibility of this phase of the work and permits the gross supervision of the entire operation. It is to be preferred to the former method in which each generating station had an organization for the unloading of coal. When the bureau was formed, it was found that each man assigned by the station knew only one operation, that is, he was either a coal-tower operator, conveyor man, crusher man, or crane operator, and that the number of employees was more than double the present number on the payroll for about 30 per cent of the present tonnage.

In the training of the coal-bureau employees the first step was to familiarize the men with each type of equipment involved, assigning the men from time to time to various pieces operating in the group until they were capable of running any part of it at one or at all plants, thus permitting a material reduction in the force. The second step was to educate the men along the lines of economical operation, encouraging them to economize in the use of wire rope, tower buckets, belts, and other forms of apparatus. By maintaining tonnage records on all the various pieces of equipment, it was possible to encourage rivalry between the men at the various unloading plants, so that it was not long before a marked increase of economy was noted.

Where an individual had been working mechanically in the past, he is now found to be giving considerable thought to his work. As an example of this, at one station the average cable life had been 30,000 tons, but after the campaign of education it jumped to more than 200,000 tons. The need of developing the men along the lines which have been briefly outlined cannot be stressed too strongly. It makes the system very flexible, and it is almost impossible for any one group of men, either due to strike or illness, to tie up any operation on the system.

Discussion

IN THE oral discussion which followed the presentation of the a paper, M. J. Andrada[2] said that the paper clearly illustrated a progressive tendency toward the use of low hoist towers in com-

[2] Robins Conveying Belt Co., New York, N. Y.

bination with inclined belt conveyors for transferring and elevating the coal for delivery to the conveyors above the bunkers. As outlined in the paper, the high hoist had the disadvantage of poor operation in stormy or foggy weather. Further, a high hoist meant high speed, as the size of the bucket was limited by the size of the hatches in the craft to be unloaded. Higher speeds naturally made operation in bad weather more difficult, as well as in good weather. The actual dead load to be handled by a hoist formed quite a part of the total power duty, whereas a belt conveyor was practically 100 per cent efficient in elevating the material, and in addition its maintenance was very low, the life of the belt running well into millions of tons of material handled.

The use of the mechanical screening was a step in advance; it facilitated to a great extent the picking of the material inasmuch as it disposed of all the fines and left the coarser material which naturally contained foreign matter. It likewise relieved the crusher to a great extent.

While locomotive cranes might be the most satisfactory unit in handling standby storage, Mr. Andrada was of the opinion that where possibly 100 per cent of the storage was turned over once or twice a year they would not compare favorably with gantry cranes, drag line, or similar equipment.

H. S. Ford[3] said that it seemed to him that the relative cost of a car and skip-hoist system and a car and pit system should be the reverse of that shown by the author for the reason that in each case the author had a car and track. In the one case there was a skip and bunker against a locomotive crane, the cost of which would be about even. He did not think the orientation would overbalance the cost of the larger pit on the crane system, and he wondered if the crane on the ground track would give better results than the skip hoist. Another factor was the maintenance and labor cost. The maintenance on a skip would seem to be considerably less than on a locomotive crane because it took less machinery and less labor.

E. F. Mullin[4] said that after a study of some 15 coal-storage plants located in various sections of the country and having capacities ranging from 3000 to 10,000 tons, the Pennsylvania Railroad Company came to the conclusion that the locomotive crane system was most economical for their work, and that they were now using it for reclaiming, and would probably use it for storage in the future. The Colfax Station of the Duquesne Light Co. in Pittsburgh stored their coal out with a bridge tramway, and packed it down in a rather crude but successful way by attaching a plank system or raft to the bucket and pulling it to and fro.

Mr. Mullin asked the author what types of belt were used on the belt installations he had described, also what types of anti-friction idlers—ball or roller bearing—were employed, and whether magnetic separators were used. He was inclined to think that in ash handling the bucket and skip would probably prove as economical as the crane and the pit.

Author's Closure

The author in closing referred to Mr. Andrada's comparison of unloading towers and elevating belt conveyors. Where deliveries were made by railroad cars over receiving hoppers, it was quite possible that a belt conveyor would compare favorably in so far as labor and maintenance costs were concerned with the unloading tower. It would, however, require considerably more space for an incline-belt system. If on the other hand vertical belts equipped with buckets were installed, the maintenance would likely be considerably higher. Since their plant deliveries were made by barge, the unloading tower was much the more desirable. In so far as maintenance costs were concerned, their unloading towers averaged approximately 1.5 cents per ton, and the belt distribution systems averaged approximately 1 cent per ton. The author quite agreed with Mr. Andrada in his remarks concerning the use of locomotive cranes. It was quite true that cranes had a limited handling capacity. For instance, at their Petty's Island coal storage, they would be in a position to handle approximately 5000 tons of coal a day on or off the Island. For tonnages exceeding this amount they would have to give consideration to heavier types of equipment.

In reply to Mr. Ford's reference to the comparative maintenance costs between a skip hoist equipped with storage tanks and a locomotive crane and pit proposition, the author offered the following analysis. Delaware Station had the skip hoist and storage tank proposition; the labor and maintenance cost per cubic yard of ash in 1926 was 20.8 cents handling 52,000 cubic yards of ash, and in 1927 it was 22.8 cents handling 57,000 cubic yards of ash. At Richmond Station with the pit and crane arrangement the cost per cubic yard of ash in 1926 was 21 cents handling 30,000 cubic yards of ash, and in 1927 was 14.4 cents handling 49,000 cubic yards of ash. The investment for the Delaware Station skip hoist, storage bunkers, and foundation was approximately $150,000, whereas the investment for the ashpit and locomotive crane at Richmond Station was $55,000. This investment in either case did not include the electric locomotive and cars as this equipment was the same at each plant. The total cost, including the interest on investment and operating charges, per cubic yard of ash in 1926 at Delaware Station was 54.7 cents and for 1927 was 53.8 cents, while at Richmond Station the corresponding figure for 1926 was 43.5 cents and for 1927 was 27.5 cents, showing a net saving for Richmond Station in 1926 of 11.2 cents and in 1927 of 26.3 cents. In addition to the reference made in the paper concerning the two methods of disposal, it might be well to call attention to the fact that the skip hoist was a single-purpose machine while the crane was a flexible piece of equipment performing various duties, and, as a matter of fact, in handling ashes the crane was only assigned to the pit for the time necessary to either load railroad cars or barges.

Answering Mr. Mullen's question regarding the type of belting used in their Delaware Station installation, he said that it was a six-ply rubber-covered canvas belt, while at Richmond they had an eight-ply rubber-covered canvas belt. At this time the tonnage on the belts at Delaware Station was approximately one million and a half tons and from all indications, these belts would go to two million tons. Both ball and roller bearings had been used on the anti-friction idlers and had been giving very good results. Their experience with magnetic rollers had not been very satisfactory, and they had discontinued their use. As a matter of fact, magnetic rollers were not essential in their systems as they had provided picking tables from which the bulk of the foreign matter was removed from the coal, and what little might get by was caught in steel trash racks located on the movable tripper above the coal bunkers.

[3] Eastern Sales Manager, R. H. Beaumont Co., Philadelphia, Pa. Assoc-Mem. A.S.M.E.

[4] Link-Belt Co., Nicetown, Philadelphia, Pa.

THE National Committee on Wood Utilization, Department of Commerce, is investigating uses for wooden containers, after they have served their purpose in transportation of commodities. The fabrication of wood containers consumes annually 4,000,000,000 ft. of lumber, frequently of good quality although of lengths too short for construction purposes. This amount of lumber represents nearly 10 per cent of the nation's entire annual lumber cut. The possibilities for an economic advantage in the profitable re-use of these containers, therefore, appears to be considerable.

What Is Yankee Ingenuity?

THE unique scholarship that has been endowed by Henry J. Fuller (Worcester Polytechnic Institute, '95), has aroused no end of comment and debate as to how it should be awarded. The only specification accompanying the gift was that the scholarship should be awarded to the entering freshman who has exhibited the greatest amount of "Yankee ingenuity."

The income from this scholarship will be sufficient to pay the college the full instruction cost of one student and to give the recipient an additional sum to be used for current expenses.

The difficulties of finding a reasonable definition for this trait, and a yardstick by which to measure it, were apparent to the college authorities at the outset, and so before establishing specifications for the award, it was decided to seek counsel among engineers and executives whose careers have exemplified ingenuity. A group of fifty men were requested to submit a definition and to suggest a basis upon which all candidates may be judged. Some members of the group begged for more time in which to study the question; other answers will be delayed until the return of those addressed.

Among the suggestions that have been most helpful is one from Dr. Michael Pupin, of Columbia University, "I define 'Yankee ingenuity' as follows: Performance of an old stunt in a new and remarkably simplified way."

Owen D. Young, chairman of the board of the General Electric Company, exhibited the trait by placing the question before the members of his staff and submitting the best answer received. The answer was:

Ingenuity, according to modern usage, suggests an inventive power which is at once nimble and effective; a readiness in apprehending or devising new and effective means for the accomplishment of any given purpose.

As for the Yankee, I do not think that he is merely the shrewd and practical trader of few words and canny wit; on the surface, of course, he is just this. Nevertheless, our history testifies to his uncanny capacity for doing the impossible.

John Hays Hammond, Jr., tied his definition to the Patent Office, a connection rarely made by boys in their 'teens.

"Yankee ingenuity" is best measured, first by the response of the Patent Office, and second, by the commercial success attained by the invention. It strikes me that it would be a difficult thing to judge it otherwise.

John F. Stevens, canal and railroad builder, past-president of the American Society of Civil Engineers, writes:

I think that it is merely the application of good, old-fashioned common sense to the ordinary affairs of life and the most important factor in their correct solution.

Frederick W. Shibley, vice-president of the Bankers Trust Co., gives the following clear statement:

The term "Yankee ingenuity" implies the inherent ability of solving a knotty problem in a simple and ingenious way, of accomplishing a difficult mechanical job without employing the customary tools.

"Yankee ingenuity" implies cleverness rather than trained skill. It is the ability to turn quickly when in a tight place. It is a knack of doing things. It is the result of intuitive knowledge rather than of knowledge gained through perception. He who possesses "Yankee ingenuity" can mend a watch or a magneto without being either a watchmaker or an electrician.

A thing accomplished through "Yankee ingenuity" is the antithesis of an accomplishment through scientific methods.

Joseph W. Powell, former president of the United States Shipping Board Emergency Fleet Corporation, states that Yankee ingenuity "is closely allied to common or 'horse' sense. A boy with common sense will find the simplest and quickest way of accomplishing his purpose with the least expenditure of time and energy. That means the application of common sense to the problem plus the energy to apply it." Dr. Willis R. Whitney, director of the research laboratory, General Electric Company, submits this interesting discussion:

Yankee ingenuity is probably persistent, imaginative activity aimed at material, or mechanical, utility. It is certainly not like "apeing" but more like "monkeying," as Robertson said. Sitting philosophers may figure on the angels per pin point but, meanwhile, a genius makes a new and sharper pin. Goodyear, Howe, Whitney, McCormick, Edison and others were successful geniuses, but we cannot include all men who "monkey," for most of them are unsuccessful. Artificial nutmegs were never made from wood, but an artificial silk purse was made from a real sow's ear by Yankee ingenuity. A lot of knowledge was necessary to do this. The trouble with mature Yankee genius is lack of knowledge to match the inborn good-will. The genius is usually the fellow who wants to accomplish some definite new thing, and continually wonders what would happen if he made certain experiments. He is likely to make these experiments regardless of everything, the history and the future.

Samuel M. Stone, president of Colt's Patent Fire Arms Manufacturing Co., gives this definition:

Exemplification of originality and skill in conceiving or fabricating devices to meet individual or public need.

but calls attention to the fact that "some of those most eligible will not have had an opportunity to demonstrate their qualifications, although such may be present to a pronounced degree."

Two architects have contributed to the discussion. One is Cass Gilbert, president of the National Academy of Design; the other, Frederick Law Olmstead, landscape expert. Mr. Gilbert states that

"Yankee ingenuity," I believe, is a term used to denote the inventive or adaptive genius of the New England boy or man whose limited resources force him to find ingenious and practical ways to accomplish with modest and homely means whatever physical result is desired. It is a form of triumph over obstacles by the use of brains rather than machinery. It is the demonstration of the saying that "necessity is the mother of invention." It is the expression of the will to conquer obstacles regardless of paucity of means. It is characteristic of New England, as it was in the old days when men had to hew the forest, split the rocks, till the soil, make the roads, build the houses, shoe the horse, fix the broken wagon wheel, and win a living for themselves and families notwithstanding the harsh conditions around them. To make every tool do double or triple duty, to make the hands obedient to the mind, and the mind to think to practical and efficient ends—this is "Yankee ingenuity."

"Yankee ingenuity" is the evidence of the self-reliant triumph of mind over matter, and is worth more to the nation as characteristic of the people than all of the "quantity production," "efficiency," "machine products," "business combinations" supported by the devastating policy of "installment buying" that could be devised. Is it dying out of the consciousness of oui people? I hope not.

Mr. Olmstead makes certain connotations, but studiously avoids a definition:

The term involves an alert readiness, in any situation, to recognize and meet facts and needs as they arise in experience, and resourceful ingenuity in devising a workable solution, not necessarily the permanently best solution, but one which does work under circumstances as they really are and which permits the prompt release of energy for other matters with a minimum of "fuss."

From an article by Herbert F. Taylor, Assistant Professor of Civil Engineering, Worcester Polytechnic Institute, in the April issue of the Journal of the Institute.

NOTE: A letter from President Earle states that the committee will rate the entering freshmen who are candidates for the scholarship upon (1) their mathematics, (2) their preparatory-school records, (3) their childhood amusements, habits, interests, and vacation work, (4) devices or articles constructed by them, (5) local reputation for originality in ideas, and (6) rating obtained on a special psychological examination.—EDITOR.

Dr. Edward B. Craft, executive vice-president of the Bell Telephone Laboratories, writes:

I should take the term to mean the ability to fashion a useful object in a novel way from unpromising or unusual material. The quality therefore involves not only inventiveness, but ability to adapt oneself to the conditions of the moment.

For example, I heard of an amateur radio operator in one of the New England towns, who maintained communication with the outside world after his town had been isolated by the recent floods by commandeering all the door-bell batteries to use as a source of power. You will also remember that the first Battle of the Marne was won by massing all the taxicabs of Paris to transport troops. These are examples of ingenuity applicable to important problems of daily life.

I think, however, that it is important to keep in mind also the fact that truly "Yankee ingenuity" would not attempt to fashion useful objects in a novel way from unpromising material if more promising materials were available. It is therefore the ingenuity that rises to meet difficulties—the sort of inventiveness which we mean when we say "necessity is the mother of invention."

For this reason I believe it will be rather difficult to measure in any other than actual conditions, although perhaps the psychologists may be able to suggest a suitable test. I should think, in other words, that the scholarship would have to be awarded on the basis of well-authenticated reports of instances of such ingenuity on the part of the boys who were being considered. In general, probably the boy's work in Scout troops would give some indication of his ability in emergencies.

The comment from Dr. Edwin E. Slosson, director of Science Service, Inc., is somewhat along the same vein:

I hope it will not be necessary for you to discover or construct an invulnerable definition of "Yankee ingenuity" in order to discover some boy who possesses the quality. I suggest that the selection might be made largely upon the basis of the boy's youthful history. Has he constructed model airplanes, demolished an alarm clock, rejuvenated motor cars, and designed radio sets? This history might be supplemented in the final boys by some kind of an intelligence test or rather ingenuity test which could be devised of the mechanical puzzles that you can find in a toy shop.

George A. Perry, mechanical engineer of the Jones & Lamson Machine Co., adds this thought to the discussion:

I suppose that "Yankee ingenuity" is, after all, just plain ingenuity, or, we might say, that quintessence of ingenuity, as of course we New Englanders all agree that Yankees are just a little bit more ingenious than other people. Probably a good definition of ingenuity is cleverness and originality in designing something or in making something to fit the needs from the material one has.

It is a little easier to define "Yankee ingenuity" as invention than it is to suggest a standard for measuring it, but if we call it originality, we find that high-school boys vary in this respect. Certainly in mathematics some boys show originality in that they insist on bringing in solutions of problems in algebra and geometry which, though correct, differ from the solutions given in the books. This largely defines invention and ingenuity, and is one of the ways in which such boys can be selected from a class.

Homer L. Ferguson, president of the Newport News Shipbuilding & Dry Dock Co., submits these crisp definitions:

"Yankee ingenuity" is that quality of mind which enables the possessor to grasp a problem and solve it in a manner at once simple, direct, and practical as well as frequently surprising.

Imagination, wit, and common sense applied to the solution of problems mechanical or otherwise.

The knack of solving difficulties.

Henry D. Sharpe, treasurer of the Brown & Sharpe Mfg. Co. and Prof. A. D. Mead, of Brown University, got together on the question and evolved the definition: "Gumption."

George E. Williamson, treasurer of the Strathmore Paper Co., says:

It seems to me that "Yankee ingenuity" is the innate ability, trait, or aptitude to think out by means of the brain and generally to work out by means of the hands some original and unique plan, device, contrivance, mechanism, or scheme which will result in marked and far-reaching benefit to mankind and to overcome by clever, intelligent and original means any and all obstacles which may be met in the attainment of the objective.

I should differentiate between "Yankee ingenuity," first, as illustrated by the sewing machine of Howe, cotton gin of Whitney, air brake of Westinghouse, Model T of Henry Ford, and, second, discoveries by accident, as vulcanizing of rubber by Goodyear.

Dr. Charles H. Herty, of the Chemical Foundation, brings in a contrast between Americans and Europeans:

The European is plodding, methodical, and patient, but frequently finds himself at sea if results are not exactly according to directions, or if unforeseen obstacles prevent the reaching of a certain goal. He thereupon becomes flustered, goes to pieces, and is all too often at an utter loss what to do.

The American, in contrast, is quick to apply common sense, originality, and initiative and fearlessness in departing from the beaten or prescribed track in order to produce the desired result. That is a great advantage which America has over Europe in industrial life today.

Editors and editorial staffs of various magazines were also among those to whom the query was addressed.

E. G. Rodger, of the *American Boy*, states that the question has been the subject of staff discussion.

We offer somewhat hesitantly the following definition: "Yankee ingenuity" is practically applied imaginative inventiveness—a trait compounded of breadth of vision, courage, determination, scientific aptitude and legitimate shrewdness.

As for the basis of award—we can think of nothing holding the elements of justice that doesn't involve the expenditure of much time and quite a bit of money. But the project justifies such expenditure, for it can be developed into one of the outstanding things of its kind.

The best plan that has occurred to us is this: ask the heads of science departments in all of the leading secondary schools of the country, and perhaps such heads in some of the colleges and universities, to suggest some tangible evidence or measurement of a boy's "Yankee ingenuity"—something that the boy has worked out under stated conditions, something that can be sent from any party of the country to the award committee to be considered by them in comparison with all entries. Probably that award committee should choose and combine from all the suggestions that come in, and finally decide and announce what that "tangible evidence or measurement" should be and under what conditions it should be prepared.

Harford Powell, Jr., editor of *The Youth's Companion*, writes as follows:

For a long time this quality was confused with meanness and sharpness. Wooden nutmegs will occur to you and so will the slickness of such types as David Harum. This is simply a debased form of the quality I am trying to suggest. The only way to drive out of the public mind is to supply frequent examples of ingenuity directed into useful and public-spirited channels.

We cannot claim that every surprising invention is the product of the Yankee type of mind. But when you find a man achieving a highly practical result from materials that seem unadaptable, you have an illustration of "Yankee ingenuity."

Arthur D. Little, consulting chemist, presents these suggestions:

I should be inclined to drop the adjective and to adopt as the basis of selection, ingenuity as exhibited by inventive ability directed to severely practical ends, and I believe this to be what Mr. Fuller has in mind.

As to the method of award, I can think of no better way that the propounding of, say, ten problems presenting opportunity for invention and requesting candidates to submit their solution of one or more of these, the solutions themselves to be later passed upon by a competent committee.

Such a committee has been selected by Mr. Fuller. Three New England executives, Frederick H. Payne, president of the Greenfield Tap & Die Co., and president of the Associated Industries of New England; Edmund C. Mayo, president of the Gorham Manufacturing Co., and Ralph E. Thompson, vice-president of the Gillette Safety Razor Co., are to prepare specifications and choose the recipient of the scholarship.

Apprentice Training for Draftsmen

By C. J. Freund,[1] Milwaukee, Wis.

It is not necessary to mention the profound influence which the introduction of quantity manufacture has exerted upon American industries during the last ten or fifteen years. As a result of new methods our industries have grown tremendously and have been almost entirely made over. Products have been standardized so that the customer has a choice of several sizes and types and selects one which costs him much less than one made to order because it is one of a great many which are all alike. Automobiles, stoves, desks, suits of clothes, shoes, and countless other articles are made in standard types and sizes and in great numbers. In fact, the ordinary American citizen has practically nothing made to order, sometimes not even his home.

For this quantity manufacture, special machinery and special arrangements of machinery have been developed. The slow and laborious machining of a single piece at a time has given way to the simultaneous machining of many different surfaces of many pieces on the same machine. Special tools, jigs, and fixtures make special operations possible and are of no other value whatever. The entire shop is one big machine for turning out hundreds and thousands of a very few types and sizes of standardized articles, all alike, in the shortest possible time and at the least possible cost.

The introduction of these methods has naturally affected the design of mechanical products. Of course, machinery must still satisfy the requirements for which it is made and must still be theoretically correct in design. However, under the new conditions in industry, these factors of design are no longer of primary importance. In fact, they are pretty much taken for granted and the most important problem of the draftsman is so to design machinery and machine parts that they can be easily and economically manufactured in large quantities. The design of an automobile of which thousands are to be made will be different from the design of that same automobile if only one were to be carefully built up piece by piece. The parts of that automobile must be designed not only so that they will function properly but also so that they can be handled and machined as easily, rapidly, and economically as possible. The parts must be designed to cost as little as possible. This cost must be determined, not by guesses based on approximate estimates of weight of metal and of time and cost of machine operations, but from an accurate knowledge based upon careful analysis.

New Conditions Imposed by Quantity-Manufacture Methods

To fit into these new conditions, the draftsman must change his traditional attitude. He can no longer hold himself apart from others. Even the rank and file of the draftsmen should have a good understanding of shop methods so that they may apply this understanding in their daily work. Unless they know something about foundry and machine operations, it is impossible for them to adapt their design to efficient manufacture. Under modern conditions a correct design must be the joint product of the engineering knowledge and skill of the draftsmen and the knowledge of manufacturing methods of the shop men. To make this possible it is necessary for the shop men to understand something of the work of the draftsmen, and it is equally necessary for the draftsmen to have a knowledge of manufacturing processes. If the draftsmen and the shop men are to work together they must have much in common. The draftsmen must consult the superintendents and foremen when a new design is begun, and many times in the course of its development. In fact, some of the best designers, not only at the present time but also in former times, have been men who were not professional draftsmen at all but were shop men who acquired considerable technical knowledge and applied this and their practical experience to their designing work.

More necessary still than a knowledge of shop methods is complete sympathy and cooperation between the draftsman and the man in the shop. The draftsman may no longer consider himself superior to the practical man in the shop merely because he happens to have a little more technical training. Unless the mechanic and the designer mutually respect each other and understand each other it will be impossible to work well together in the development of a design for a product which is both theoretically correct and easily manufactured. As in all other human relations, any lack of cooperation between draftsmen and shop men is very likely to be the result of misunderstanding and should disappear upon better acquaintance.

Experience has shown that the best way to overcome these difficulties is for the draftsman to spend a considerable period of time in actual shop work. After all, there is nothing like first-hand experience. Nor can this actual shop work be replaced by any number of inspection trips, walks in the shop, attendance at meetings of shop men, or any method other than actual work. The reason for this is perhaps not so much technical as psychological. The shop man is suspicious of any one who pretends to know shop methods and still indicates by a thousand and one imperceptible little signs that he has never hardened his hands by the use of tools. On the other hand, the shop man welcomes as a brother any draftsman who has actually worked side by side with the mechanics in the plant.

The ideal shop training for the draftsman is a general training. Some time should be spent in all departments of the machine shop, and some time should be spent in the foundry. There is no intention of turning out even semi-skilled mechanics by means of this shop experience for draftsmen. The purpose is not only to acquaint the draftsman with the methods in use without going too much into detail; but especially to make him acquainted with the atmosphere of the shop and to give him an opportunity to mingle with mechanics and to sympathize with their attitudes and habits. This will prevent his antagonizing them after he begins actual drafting work.

Courses Devised for Training Drafting Apprentices

With these various considerations in mind, the Falk Corporation established apprentice training for draftsmen and has conducted these courses for nearly five years. The plan of work for the drafting apprentice was drawn up after a very careful examination of the experience of other corporations in the training of draftsmen, a thorough analysis of the requirements of the occupation and frequent discussions with officials, drafting-room chiefs and shop executives. Under this kind of apprenticeship, drafting skill is imparted by actual work on the job

[1] Apprentice Supervisor, The Falk Corporation, Assoc-Mem. A.S.M.E.

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under every-day conditions. The schedule of work for the regular or four years drafting apprenticeship is as follows:

Tracing, Blueprinting	2650 hours
Lathe	700 hours
Planer	200 hours
Shaper	200 hours
Milling Machine	400 hours
Drill Press	100 hours
Erecting	700 hours
Miscellaneous Foundry Floor Work	1000 hours
Detailing	3200 hours
Special Work	610 hours
	9760 hours

The following course is available for high-school graduates:

Tracing, Blueprinting	2450 hours
Small Lathe	400 hours
Planer	100 hours
Shaper	200 hours
Milling Machine	300 hours
Drill Press	100 hours
Special Machine Work	220 hours
Erecting	500 hours
Detailing	2450 hours
Miscellaneous Foundry Work	600 hours
	7320 hours

Ordinarily the apprentice begins work in the blueprint room and while there becomes familiar with the general procedure in the drafting room. Thereafter he begins his period of tracing, and when this is partially complete he goes into the plant for the full round of shop work. When this is completed the tracing is resumed until the required number of hours have been completed, whereupon the apprentice concentrates on detailing and sometimes is given layout work toward the end of this course, if his ability and diligence warrant this. A portion of the contract time is assigned to special work which makes it possible to give the apprentice additional instruction in any department in which this seems to be necessary, or he may do some work in the clerical end of the drafting room or be assigned to any task whatever which will be of benefit to him in the course of his training.

Usually the apprentices are paired with experienced draftsmen and work side by side with them throughout their tracing and detailing experience. In this manner the older draftsman can exercise supervision over the boy without interrupting his own work too much, and the apprentice can be given necessary information with minimum loss of time. The Apprentice Department is responsible for the execution of the apprenticeship contract. It employs apprentices and dismisses them according to requirements, transfers them from one department to another, and exercises general supervision. The apprentices report to drafting-room or shop department heads for work, and their status in these departments is no different from that of a regular employee as far as the daily work and deportment are concerned. Under the foregoing arrangement, the mechanic and draftsman, the foreman and drafting-room chief are, after all, the real instructors of the apprentices, and to their interest and painstaking efforts must be largely ascribed whatever success has been had with apprentice training for draftsmen.

A year of shop work is included in both the regular and high-school-graduate contracts in order to give the apprentice the familiarity with shop methods and sympathy with shop men which are so essential for the draftsman. The distribution of shop work is the result of considerable trial and experience, and has been found to give as nearly as possible what the drafting apprentice requires. The drafting apprentice who returns to the board after completing the prescribed program of shop work has a much different attitude toward the shop and the mechanic, and a better knowledge of shop methods than the old-fashioned draftsman.

The apprenticeship law of the state of Wisconsin requires each apprentice to attend a vocational school one-half day per week during the school year until he has completed 400 hours of school attendance. The Falk Corporation and a number of other metal-trades plants in Milwaukee require apprentices to attend school during the entire apprenticeship period, and the Milwaukee Vocational School has not only consented to this but has given excellent service and cooperation in every way. No attempt whatever is made to give the apprentices theoretical instruction at the shop; this entire responsibility is intrusted to the authorities of the vocational school. The course of instruction for drafting apprentices includes arithmetic, practical algebra and geometry, shop trigonometry, slide rule, strength of materials, elementary statics, shop drawing, and elementary mechanism, and also short periods devoted to English, citizenship, hygiene, and safety. High-school-graduate apprentices are given credit against this course for whatever work they have completed in high school. The instruction of the apprentice is accomplished by means of a quite remarkable arrangement of unit lessons, so that each student can proceed as rapidly as his ability will permit without being retarded by the progress of the class and, on the other hand, without having the class get ahead of him if he cannot maintain the average pace. Of course, the less capable apprentices do not complete all of the prescribed course. This makes little difference, as the more advanced of these studies are not required for ordinary drafting work. On the other hand, the brighter boys easily finish the prescribed work, and are then permitted to continue on special problems or assignments in which they are interested and have displayed special ability.

Results Obtained from Training

Very few difficulties have been encountered in conducting these apprentice courses during the period of over four years since they have been established. It has been found easy to adjust the training schedule of work to daily conditions. Shop officials have made no objections to receiving drafting apprentices for their year of work in the plant, because they have been far-sighted enough to understand that they will be more than repaid by the improved attitude and work of these same apprentices as draftsmen later on. Occasionally apprentices have been disappointed with the large proportion of routine work in the drafting room and the small proportion of time which is devoted to the solution of fascinating technical problems. Also, they have occasionally been annoyed by the repetition of similar assignments and have felt there was not a sufficient variety of work. A careful explanation of the conditions existing in any drafting room and the necessity of a certain amount of repetition to impart skill have usually overcome these objections in the first discussion. However, it has been necessary to select young men for apprentice courses very carefully because of the great popularity of drafting work at the present time, and because of the tendency of many boys to select the drafting occupation for the reason that it appears to be extremely easy work.

The success of these methods of training has demonstrated their correctness. The draftsmen who have graduated from these courses are almost invariably far above the average in every way.

Seven of the graduates are employed in the plant and are giving a good account of themselves. They are not merely skilled draftsmen, for several years of work in the plant have made them thoroughly familiar with the methods, policies, and products of the Falk Corporation. They have spent the most impressionable period of their lives in a special training course, and have become exceedingly loyal and reliable. They are the veteran survivors of a strenuous training campaign. Of these seven who are working in the plant, one has become a minor official in the production department, two are checkers, and the other four are far superior to the draftsman who has blundered into a drafting room and almost in spite of himself has acquired a certain amount of drafting skill. In addition to the seven who are employed in the shop, a number have gone to other employers, and, as far as can be ascertained, all are doing very well and are considered to be high-class draftsmen.

These young men have made ample compensation for whatever trouble and expense were incurred in training them. It is a great satisfaction to realize that the drafting-room organization is beginning to develop from within, that the work is being done better by men who are thoroughly familiar with it, that policies and principles can easily be executed through men who have been with the organization a number of years, and to know that a training program of this kind most effectively fulfils the responsibility of each employer for supplying his share of the trained men who are required by industry. It is merely one little factor in the great movement in favor of apprenticeship which has so rapidly become an important activity in American industrial life.

Discussion

A WRITTEN discussion was submitted by D. W. Castle,[2] who said that the experience of the Joliet schools had been identical with that of the author. Their drafting students, he wrote, were high-school boys and not apprentices. They worked in the drafting room three hours per day for four years and studied related science, mathematics, and a course in shop methods where they received practical shop training. In general this shop training took an average of one hour per day, depending upon the program of the shop which gave the instruction. This time was approximately evenly divided between the pattern shop and the various phases of machine-shop practice.

J. E. Goss[3] wrote that the Brown & Sharpe Mfg. Co. had had a successful experience with a similar training course where the student spent seven months in the various shop departments and returned to the drawing room with a better technical knowledge and a cooperative spirit. He explained that they accepted only those having a technical-high-school training or its equivalent. In the drafting room and shop the apprentice was given a wide variety of work. The company did not get satisfactory draftsmen and designers from outside but made them, and the training course was not a matter of choice but a necessity.

William Lester[4] expressed the opinion that most companies which depended on secondary technical schools for training their draftsmen got but inferior men, due to the method of training and the very limited amount of or actual absence of shop training. He thought the course could well be raised to about 1200 hours—to be spent in the shop departments. He raised the question whether it would not be a good idea to supplement the foundry training by about 600 hours of pattern-shop work and 300 hours of forge- or plate-shop layout work. And to further familiarize the apprentice with manufacturing limits and tolerances about 300 hours in the inspection department, he thought, should prove very valuable.

C. W. Cross[5] contributed a written discussion in which he outlined the apprentice system inaugurated on the N.Y.C. Lines in 1906 and told of its success. The purpose of the courses was to recruit skilled workmen, foremen, draftsmen, and some higher executives from the ranks.

There were three grades, he wrote, the regular apprentice, the helper apprentice, and the special apprentice. The first was for boys 17 to 21 years, with a high-school education or equivalent, who were trained in important subjects at two sessions of two hours each week. Attendance was compulsory and under pay and the course lasted four years. The helper apprentices were young men 21 to 30 years of age who had had two years continuous service as helpers in the shops. These were allowed to complete the course in three years. Mechanical-engineering-course graduates, 18 to 26 years of age formed the third grade and were placed on regular work in the shop and assigned special work on tests and selected duties. They did not attend the school. The subjects studied were planned to fit into actual solution of shop problems. Instruction was largely individual and confined to the actual work required on the railroad. Schedules had been arranged for the various trades.

Mr. Cross concluded by giving an outline of the courses followed in the various trades, pointing out that the best results could be accomplished only by a plan embodying instruction in standard practice of the railroad, and telling of the success the company had had in its work.

In the oral discussion that followed Erik Oberg[6] suggested that a reading course would be a valuable addition to the course outlined by the author to broaden the actual experience of the men—a course that would cover all broad subjects of shop work. Another importance of the course, he pointed out, was to emphasize to the draftsman that drawing was only a means to an end and not an end in itself. The important point was to secure the end and not the most finished drawing. It had been Mr. Oberg's experience that few departments in business were less efficient in the use of time than the drafting room, and that the young men should be taught to be just as efficient in the use of time as any machine operator.

W. T. Hunt[7] spoke of the course conducted by the Tri-Cities Manufacturers' Association, patterned after the Milwaukee system. The association, he said, did not have a drafting school because they felt a man must first learn what to draw by actual practice in the shops. After a couple of years of experience in the pattern shop they would try a young man out in the drafting room.

H. W. Fitch[8] said that the N.Y.N.H. & H.R.R. followed much the same plan and had found that actual experience in the shop made for better draftsmen; further, that those who were ambitious had plenty of opportunity to learn in the outside schools.

A. S. Kinsey[9] pointed out that many of the men who did not graduate from Stevens went into drafting rooms and some later reached as important positions as some of the actual grad-

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[8] Assistant Engineer, N.Y.N.H. & H.R.R. Co., New Haven, Conn. Jun. A.S.M.E.

[9] Professor of Shop Practice, Stevens Institute of Technology, Hoboken, N. J. Mem. A.S.M.E.

uates. He said he had noticed two types of men in the drafting room, the one who would remain a draftsman and the other who would read and get information as to methods and principles, and advance to positions of greater responsibility. The problem of the drafting room, he thought, was to train the intelligence rather than to develop the skill of the student of mechanical engineering

J. E. Yorkston[10] said that in the last 20 years there had been a great falling off in the immigration of trained men, and that America in order to keep its apparatus the best obtainable would now have to train apprentices to take their places, and train them better than they had been trained abroad. The most important point, he thought, was the selection of the young men to be trained. His experience had been that he got better material by selecting the cream of the grade-school pupils who had had a little high-school training rather than by taking graduates. This was because the cream of the actual graduates generally went to college, leaving the duller ones for apprentice training. He expressed the opinion that a good engineer must be a draftsmen, as unless one was able to put down on paper what he visualized he could not expect another to transmit his thoughts.

In his closure the author, Mr. Freund, said that taking the best machinists into the drafting room had been given up by his company, both because they did not think that was the best way to determine a potential draftsman, and because they did not consider drafting more important than good machine work. He endorsed the remarks of Mr. Yorkston as to the need of replacing the apprentices formerly secured through immigration, and declared that this need would become felt more seriously later. He mentioned the fact that his course frequently took in non-engineering college graduates as apprentices, but they generally wanted foundry training, mostly because others shunned it.

Further Facts Regarding Steel-Wool Manufacture

STEEL wool consists of long, relatively strong, silky and resilient fibers of polygonal cross-section shaved from steel and having three or more sharp edges. These characteristics render it an excellent abrasive for use in the woodworking industries in place of sandpaper, for cleaning cooking utensils, and for preparing surfaces for painting. A paper describing the industry, its art, extent, and recent development was presented by Crosby Field at the Annual Meeting of the A.S.M.E. in December last, together with details of the automatic continuous machine used by the company with which he is connected for the production of steel wool.

Following the presentation of the paper numerous questions were asked of the author by Messrs. M. D. Niblette, C. V. O'Brien, C. W. Stengel, Frank Short, Frederick Franz, and Prof. W. T. Magruder, chairman of the session at which the paper was presented. To these he undertook to reply.

Concerning the strand of 100,000-ft. length mentioned in the paper, Mr. Field said that this was made by welding together several wires and then shaving the entire number as one length. The length of the shaving was about 60 per cent of that of the wire from which it was cut.

The process started with a wire $^1/_{10}$ in. in diameter, which was separated into some 40,000 individual fibers. As the operation was continuous the wire was at once reduced to scrap under the action of the numerous cutters, the scrap amounting to between 10 and 20 per cent of the original section.

The apparent clearance angle was the angle included between the axis of the cutting knife and a tangent to the top of the wire. The true clearance angle was less, being the side angle of the serration of the knife with the surface of the wire. Using a method devised by A. L. DeLeeuw[1] for use in the case of thread chasers, and which was applicable, the values at the top of the second column had been worked out.

The problem was to get the smallest true clearance angle possible, because that gave the longest fiber.

In regard to the "jump" of the tool, in making steel wool, if a knife struck a hard spot in the metal and was not permitted to climb out, it would immediately burn up, break off, or dig into the wire, and as this was very thin, it might cut through it. The knives were accordingly arranged so that upon meeting any hard

Angle included between sides of teeth, deg.	Apparent or bottom clearance angle, deg.	True or side clearance angle, deg.	min.
60	11	5	32
60	16	8	9
90	11	7	48
90	16	11	13
60	22	11	29
90	22	16	4

spot a knife, which was normally floating, would immediately jump out of contact with the wire, the cutting ceasing temporarily, and the hard place would travel on until it came to a knife specially made for cutting out hard spots, after which the first knife would return to position and begin cutting anew. If, however, it struck a very hard spot on the wire and lost its cutting teeth it would not produce the proper grade of wool, and would have to be replaced.

As to the grade of steel wool to employ, the coarsest one should be selected that could be used without scratching the work. This would last longer, cut deeper, and be cheaper than any other.

A bundle of wire weighed about 300 lb. and would last only about 20 minutes in the machine. Accordingly two or three tons of wire were put on a drum, the ends of the separate bundle being welded so as to form a continuous wire roughly 200,000 ft. long, and this would serve the machine for several hours.

There were a vast number of uses to which steel wool could be put. It had not, however, as yet been applied in machine-shop work. With emery and sandpaper the cutting was done with a sharp point. With steel wool it was done with a sharp edge. The finish obtained with steel wool was one made by a multitude of very fine triangular scrapers, and the surface obtained was comparable to that in a scraped bearing.

A. E. Flowers, in a written communication, called attention to the author's altogether novel proposal to use a free, floating cutting knife, controlled automatically and solely by inertia and friction, and adjusted to a predetermined cutting pressure, appropriate to the fineness of steel wool desired, by the pressure due to the weight of the knife and knife holder. This radical proposal at once did away with the careful and minute, almost micrometer-like, hand adjustment previously employed. Hand adjustment necessitated continuous attention by a specially skilled operator who was kept fully busy when attending to 12 to 24 knives. Quantity production had thus become feasible at moderate costs for labor and floor space.

[10] Consulting Mechanical Engineer, General Electric Co., Schenectady, N. Y. Mem. A.S.M.E.

[1] "Metal-Cutting Tools," by A. L. DeLeeuw, 1922 edition, p. 277.

The Limiting Temperature in Central-Station Operation—A Discussion

At a meeting of the Metropolitan Section of the A.S.M.E. held in New York on January 30, V. T. Malcolm presented a paper in which he discussed the above-mentioned subject. As a result of his investigations he stated that he believed that at each temperature of a metal under test there was a stress which if exceeded would cause fracture, though equipment might give satisfactory service operating at this temperature with loads greater than the critical stress for many years.

His conclusions were that the design of equipment must be based upon the strength of metals at operating temperatures, over long periods of time, and that other properties such as thermal expansion, thermal conductivity, chemical stability, resistance to wear and abrasion, etc. must receive greater attention than in present engineering practice. These latter factors would probably govern actual design, but the first and basic requisite was that of physical strength at the proposed temperature.

The paper, which was published in the February issue of Mechanical Engineering, p. 137, includes ten charts giving data on certain alloys which the author considers safe for operation at 1000 deg. fahr., and which are satisfactory in such service as regards wear resistance, chemical stability, and coefficient of expansion.

Several written discussions of Mr. Malcolm's timely paper were contributed by engineers prominent in the power field, and appear below.

Geo. A. Orrok.[1] Mr. Malcolm's paper is a thoughtful and suggestive plea for much more and much more careful testing of the qualities of the material which we are using in our steam practice. He understands that the whole subject is controversial in the highest degree at the present time, and that the two camps are divided between those who believe that creep exists at all temperatures and stresses and those who believe that it commences at some fixed stress and temperature which may or may not be the limit of proportionality. I have just been going through the literature and tests available today where the values of Young's modulus have been obtained for many materials and many temperatures. The definite straight-line law so often quoted and which has been crystallized in Kaye and Laby's book on "Physical Constants," and the Sutherland formula, which is a cubic and bears no relation to the Kaye and Laby straight-line law, have each their advocates, and when it comes to Poisson's ratio we are dealing with conjecture almost entirely, and no one can say today whether this ratio is constant over a temperature range or varies directly or otherwise with the temperature. Such conditions as these may bring about the various curves which have been given by many authorities for the creep limit of various materials, and which represent about the best we know at the present time of high-temperature behavior of the usual materials for boiler and steam-pipe apparatus. Those of us who have seen the beautiful experiments made with the single crystal of copper or aluminum, who have listened to the theories about the order of the crystals in any metallic body, together with the ideas of what holds the crystals together, and the strength of the cement or interlacing in proportion to the strength of the crystals themselves, may perhaps have some conception of the amount of work which must be done by the experimenter before this subject can be brought to a satisfactory working theory. Meanwhile it is perhaps better to consider that creep for a practical purpose commences at some certain stress at any given temperature, and that this stress is probably at or a trifle below the limits of proportionality.

There have been many excellent papers on this subject, one of the most suggestive having been given before the Institution of Mechanical Engineers at the Northwestern Branch in England, on April 21, 1927. The author, Mr. Bailey, tackles the subject in a very interesting manner indeed, and near the end sums up somewhat as follows: "The relation between stress and strain will no longer be represented by Hooke's law, but by an exponential expression tending toward this law as a limit at low stresses. There are thus good reasons for expecting better service from metals at high temperatures than would be expected from elastic considerations, and the action taken at the Langerbrugge station therefore has some justification."

E. R. Fish.[2] The question of limiting temperatures of plant operation may be divided into two distinct parts—one as regards the thermodynamics, and the other the one treated by Mr. Malcolm, that is, the ability of the materials of construction to stand relatively high temperatures in connection with relatively high pressures. The continuously rising demands of turbine designers for higher and higher pressures and temperatures have resulted in emphasizing the question of the limit of the present usual materials as regards these factors.

After having carefully read Mr. Malcolm's paper, I find myself in hearty accord with everything that he has to say. The quotation from *The Engineer* to the effect that "progress is hampered by the inevitable inertia of established practice," is only too true. However, that is one of the ways of playing safe, for in matters such as the one under discussion—how close we can approach to the danger limit—we must to a great extent be guided by experience, and progress by that method is necessarily by short steps.

If the present materials, the characteristics of which at relatively low temperatures are well understood, can be continued for considerably higher temperatures, it will be very much better than to have to introduce new materials of construction forthwith. If newer materials, in time, prove themselves better adapted they will gradually become adopted as their characteristics become better known, and as the mills become prepared to supply such material in quantities and at reasonable prices.

Ill-advised statements made on personal opinion, prejudice, or some hypothesis of a single individual should be accepted with great hesitation. Broad conclusions must not be drawn from narrow premises, and it is therefore necessary to feel the way slowly, and to await the development of soundly justified conclusions.

There are but two ways by which we can determine how far the use of present materials is justified in connection with high-pressure-steam installations. First, by the gradual accumulation of experience gained by short and cautious steps, and secondly, by laboratory investigations covering a very wide range of conditions and materials, both as regards physical and chemical characteristics. I know that one large concern is

[1] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

[2] Vice-President, Heine Boiler Co., New York, N. Y. Vice-President A.S.M.E.

having a painstaking investigation made by their research department along the lines covered by Mr. Malcolm's experiments.

From what little I know of it, it seems evident that the time element at elevated temperatures is very vital in the ability of the usual run of low-carbon steels to carry stresses of any magnitude. It is of course this factor that Mr. Malcolm particularly dwells on, and it seems to me a very much greater amount of light on it is still needed.

The consistency of the curves of the characteristics of the special metals tested by Mr. Malcolm would seem to indicate rather definitely what can be expected of them. Without considerably more information as to their adaptability to high-pressure boilers and piping, we must continue to depend upon and use the present grades of open-hearth low-carbon steels.

Whether the result of the investigations above referred to will be made public or not, I do not know. It will be regrettable if they are not.

Extensive research into this whole matter would seem to be a very legitimate field for the activities of the Engineering Foundation, the A.S.M.E., or the U.S. Bureau of Standards.

Walter N. Polakov.[3] The subject of the changing tensile strength of steel with increased temperature is particularly important not only in central stations but in industrial plants which economically justify still higher degree of superheat, as exhaust steam is utilized in processing of manufactured goods.

Ordinary chrome-nickel steel as manufactured by Krupp shows a drop of tensile strength from 106 kg. per sq. mm. at 200 deg. cent. down to 89 kg. per sq. mm. at 400 deg. cent., and to 17 kg. per sq. mm. at 600 deg. cent., while special high-grade alloy steel for high temperatures shows a more uniform characteristic—from 49 kg. per sq. mm. at 200 deg. cent. down to 34 kg. per sq. mm. at 600 deg. cent.

In European practice, therefore, Siemens-Martin steel with a tensile strength of from 60 to 70 kg. per sq. mm. (80,000 to 90,000 lb. per sq. in.) at ordinary temperature is usually specified for high-pressure, high-temperature boiler tubes. At 580 deg. cent. and at the elastic limit, according to Prof. Dr. Löffler of Charlottenburg, such steel has a tensile strength of only 10 kg. per sq. mm. (14,200 lb. per sq. in.).

Still harder steel must therefore be used for high-temperature pipes, valves, and fittings, provided it is readily weldable, at least in the oxyhydrogen gas flame.

Usually the data on tensile strength are determined by tests of 15 min. duration. Obviously for longer tests and in practice the figures obtained prove proportionately lower.

The same authority therefore recommends "that the physical properties of the materials compiled by metallurgical investigators for use in textbooks, pocketbooks, price lists, etc. be referred to the tensile strength at the elastic limit and be given for temperatures ranging up to at least 600 deg. cent. (1112 deg. fahr.), and that a clear statement be given as to how the figures were determined, i.e., whether they refer to a normal or to a specially treated material. Only with such data at his disposal can the designer judge whether a material is suitable for his construction."

Mr. Malcolm's paper is a step in the right direction, and it is hoped that metallurgists will heed his advice.

C. G. Spencer.[4] The statement quoted from *The Engineer* that progress in introducing higher steam temperatures in central-station practice is hampered by the inertia of established practice, which has fixed 750 deg. fahr. as a maximum, is a challenge to engineers responsible for major decisions in station design. The potential gains in operating economy to be made by higher temperatures are well known and hold out the incentive. The inertia of established practice is hard to overcome, but since the war established practice in the field of steam engineering has largely been overthrown and a marked tendency shown toward innovations. Established practice, in the writer's opinion, has but little bearing on this problem.

Inconsistencies and contradictions in the results of published tests of the behavior of metals under high temperatures, referred to by the author, deter responsible engineers from committing a design where millions in investment are involved and continuity of operation is essential in a field where research has not definitely established the safe limits.

While the gains referred to and which can be reduced to fuel savings in dollars per year are great, there is a limit to the expenditures that are justified thereby. The results given of creep tests of chrome-nickel, chrome-tungsten, and other alloy steels are valuable and interesting, but a high-temperature metal is essential for the whole system starting with the boiler and ending with the turbine. These alloy steels, if the writer understands correctly, are suggested for valve trimmings and some fittings which form but a small percentage of the total tonnage required.

The writer is not qualified to discuss this subject from a metallurgical point of view, so cannot express in metallurgical terms a theory that is heard with recurring frequency to the effect that there are other properties of available metals than those usually considered that determine the limit of temperature. It may be that research will show that 750 deg. fahr. is not the limit for the metals now employed. This is borne out by European practice where the author states that manufacturers in France will accept contracts up to 850 deg. fahr., and also by various installations at higher temperatures and pressures in the oil industry in this country.

Continued study and research, of which this paper is a good example, will eliminate the inconsistencies and establish safe limits. The central station as laid down today is not the place for experimenting on radical changes in the direction of higher steam temperatures.

The Author. The author is very well pleased with both the written and oral discussion from the prominent engineers who commented on his contribution—which was simply brought forward as the result of some of his metallurgical researches; yet no one who follows the progress of this type of work can fail to be impressed by the very important contributions to the literature by the several investigators on this subject.

We all, however, must realize that the real value of such work must depend upon its ultimate industrial application, and the question presents itself as to what extent the results obtained by intense research will be applied directly or indirectly to industrial uses.

The author has tried to present the problem in a non-technical manner because he finds that real difficulty lies in the fact that a technical presentation is almost useless to the practical man who wishes to apply the results to his particular branch of industry. However, we cannot fail at times to enter into technical discussion regardless of how non-technical the original material appears to be. This particular phase is brought forth by Mr. Orrok in his discussion.

With regard to the subject of creep, as far as the author is concerned, he has assumed a definite state of mind, and that is, that the short-time tests are of no value except in an academic way or in the beginning of a program of research to segregate

[3] President, Walter N. Polakov & Co., Inc., New York, N. Y. Mem. A.S.M.E.

[4] Vice-President, Baker & Spencer, Inc., New York, N. Y. Mem. A.S.M.E.

certain materials which are not worth while investigating by the longer methods.

The creep test described in the paper consists in determining the flow of metals at various stresses and at 1000 deg. temperature. It has been clearly stated how indications of a critical-stress value were obtained.

The question as to whether there is a particular critical stress for a metal at any temperature which the metal can withstand for an *infinite time*, cannot of course be determined by any direct experiment.

Measurements of flow were made over periods of 4000 to 6000 hours with the object of approaching critical conditions as closely as possible. However, even this method of investigation does not tell the complete story, and to strengthen the author's viewpoint in regard to creep, he presents a curve (Fig. 1) showing

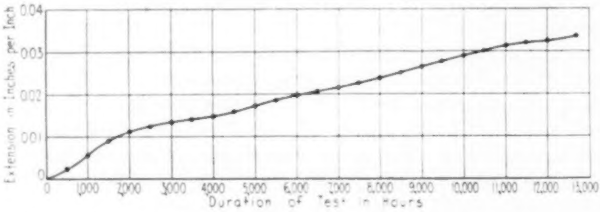

Fig. 1 Long-Duration Test on Cast Chrome-Nickel Steel
(Constant temperature, 1000 deg. fahr.; constant load., 7635 lb. per sq. in.)

a test on cast chrome-nickel steel for a duration of 14,000 hours or nineteen months at 1000 deg. temperature and 7635 lb. loading per square inch. It may be noted from this curve that creep is continuous, whereas, if based on tests of approximately 2000 to 6000 hours duration, the curve would be practically flat, with the result that 8000 lb. per sq. in. would have been considered the critical stress, as shown in the author's diagram, Fig. 7.

The author as a member of the Joint Committee on the Properties of Metals at Elevated Temperatures, pointed out in August, 1925, the fact that he believed the terms designating proportionality and elastic limit had been used indiscriminately, and he still believes there is quite a misunderstanding as to the meanings of the various terms, as regards the limit of proportionality and so-called elastic limit.

It is believed that the standard methods as suggested by Committee E-1 of the American Society for Testing Materials are not entirely satisfactory for the different materials. For certain metals the stress-strain curve breaks more or less sharply at the so-called elastic limit, so that the rate of sudden increase in the rate of elongation is quite sharp. A number of metals, however, do not register this sharp break but bear gradually away from the straight line and give a shallow, flat curve. With such materials it is very difficult to locate the elastic limit by sudden increase in the rate of elongation, because the rate of increase is so gradual that the observer cannot detect it until after a certain amount of stretch has taken place.

Further, by referring to report of Committee E-1 as presented to the American Society for Testing Materials, in June, 1925, we have the following information:

> That by using any known method, the value determined for either proportional or for elastic limit is somewhat arbitrary, the value depending upon the various test conditions, among them the precision of the apparatus, the scales to which the stress-strain diagrams may be plotted, the tolerance allowed before it is judged that there exists a proportional deviation from the law of proportionality of stress, or any appreciable permanent deformation upon release of stress.

In other words, investigators using apparatus of varying sensitivity would get altogether different limits of proportionality.

The author pleaded at that time for some standardized extensometer on which might be based the results of the several investigators, as the great variations that we see in the present curves are surely based on the fact that investigators are using extensometers of varying sensitivity.

Wonderful progress is now being made by physicists with the use of the X-ray and highly sensitive instruments for determining slight changes in metals, and it is not out of order to say that a good many of our present physical laws may be changed in the near future.

The ordinary conception of a solid represents it as a portion of matter possessing rigidity. The distinction, however, has very little value from a scientific standpoint because it is indefinite, and it has been shown that flow can be induced in nearly any solid by the proper application of a sufficient force. This was first brought forth by M. Tresca as the "Tresca Hypothesis."

It is now recognized that a great majority of substances can exist in solid forms, which are bounded by plain surfaces so oriented to one another that the whole possesses some degree of symmetry. A substance in this state is crystalline, and the state is called the crystalline state of aggregation. The constituent atoms in the crystal are arranged in a definite pattern which is regularly repeated throughout the body of the crystal.

The author in his paper "Investigation of Bolt Steels"[5] states that steel is an aggregate of crystals and that when metal undergoes plastic deformation due to certain strains, the crystals are deformed in the same general sense as the metal. This change of shape in the crystals is accompanied by a process of slip or gliding by which layers of crystals slide over one another along certain gliding planes. When slip is severe or localized the molecular disturbance at the slip surface increases the quantity of amorphous cement which has its genesis in the gliding action.

Troendly and Pickwell[6] concluded that if amorphous metal is generated or produced by the mechanism of slip, it is not hard and brittle and above all does not have a higher unit static strength than the crystal from which it is formed. They devised a new theory on the mechanics of overstrain and the strength of materials which might be termed as plastic transfer of the proportional range.

In observing the behavior of a material from a stress-strain curve the latter is to be looked upon as a record of the aggregate action rather than of the individual crystal behavior.

At the present time many facts have been gathered on this subject, and with the rapid development of the X-ray significant results may be obtained in the near future. In the present state of our knowledge we have no basis to proceed upon other than the belief that the cause of the strength and elasticity in metals lies in the existence of interatomic forces between the intimate particles of which they are composed.

All our current knowledge of metals in regard to their engineering properties is of a purely empirical nature. We know a large number of facts as the result of accumulated experimental results, and upon the basis of these results we are able to build our structures. However, can we stop at that point when a deeper insight is offered to us?

The exact manner in which the atoms of crystals arrange themselves is apparently a small matter to those who are concerned with the mechanical behavior of metals in large masses consisting of many thousands of these minute crystals, each one of which in turn consists of thousands of millions of atoms. Nevertheless the relationship between the two is too close to be ignored.

The elastic and plastic deformation of metals are of fundamental importance to the engineer, and since it is now clearly recognized that the elastic phenomena reside within the space

[5] Trans. Soc. for Steel Treating, February, 1927, p. 191.

[6] Ibid., August, 1924, p. 169.

lattice itself, the behavior of the atoms in the lattice becomes a matter of great interest.

It is true that for the present purpose of design an empirical knowledge of certain values of a given material is determined. The question arises, however, how are these values determined, and are the results of certain values obtained by investigators using the less sensitive apparatus applicable to industry, or are we limiting our industries from further advancement, because of the low proportional limit shown by research investigations?

The author's present opinion is that we are dealing with such small increments of strain that we are about to place industrial design on the same basis as exacting research. This he does not believe is going to be the effective solution of the problem, because we do know that certain materials whose design have been based on creep tests which show a certain amount of deformation not exceeding 4 per cent over a period of several thousand hours, are standing up very well under both the pressure and temperature of operation.

Mr Orrok mentions the beautiful experiments with single crystals, and the author believes they are of particular value, and is glad to note the interest of engineers in this subject.

M. J. Buerger[7] has given some very fine data on this subject, and he states that probably the most puzzling features observed during a single crystal deformation test are the appearance of slip striae on the surface of crystals and the strengthening of the specimen.

While the first phenomenon is mainly of theoretical interest, the latter is fundamental to all strain-hardening and cold-working processes in which the deformation occurs by translation.

It has been observed that after a certain amount of initial stress is applied, the surfaces of the crystal becomes covered with sets of parallel striae or rings which appear to divide it into thin slabs or slip blocks. The striae are traces of rational crystallographic planes along which shearing movements are localized, these movements providing the strain which accompanies stresses applied beyond pure elasticity.

As stress is applied to the crystal beyond the pure elastic limit of the weakest pairs of planes, the restoring forces of the ions in these planes are overcome and translation takes place. As it does so, the original, closely nested disposition of distortions is altered and a new, less compact distribution approached.

Since by hypothesis the original distortion was that of least potential energy, it is obvious that the potential energy of the lattice must be increased by translation. The distortion aureoles tend to assume positions near one another, where, not nesting so compactly, they expand the lattice.

The force necessary to continue translation thus consists not only of that necessary to overcome interatomic friction, but also of that necessary to increase the dimensions of the crystal. In other words, planes must not only be slipped apart during deformation, but they must also be lifted away from one another.

This is a partial confirmation of Beilby's findings that the specific gravities of crystals decrease on cold working. The process of distortion continues until the lattice is in an almost unstable condition; that is, until further translation of any pair of planes which so far separates them that cohesion under the load used would no longer be possible. Further increase in stress then produces cleavage. The really fundamental question, however, is whether such a permanent change of shape is due to a permanent or plastic distortion of the lattice; this question is yet to be answered.

With regard to the modulus of elasticity as determined from the ordinary stress-strain diagram, the author believes that if an examination of a number of curves presented by investigators were calculated, tremendous variations would be found in their results.

The author has not read the paper by Mr. Bailey to which Mr. Orrok refers, but he has read a number of his papers and has the highest regard for him as an investigator into these problems, and believes that his statement that the stress-strain relation will no longer be represented by Hooke's law but by an exponential expression, is correct; a similar statement was made by the author in closing the oral discussion.

There is no reason to doubt that the aggregate of crystals composing steel will not have the same general characteristic as the single crystal.

W. Geiss found the rate of flow v for single-crystal wires, was connected with the load P by an exponential equation $v = \frac{a}{P} e^{bP}$, where a and b are constants. This function is independent of the time t during which the load is applied. Experiments were therefore made to determine the relation between rate of flow and time, using Pintsch single crystals of tungsten. The rate of flow was found to be an exponential function of the time, and the equation $v = v_0 e^{n(P - P_s)t}$ is derived, where v_0 and n depend upon the load ($n > 0$), and P_s is the load at which the rate of flow is a constant. The rate of flow is derived as a function of both time and load, and the equation is $v = Ae^{B(P - P_s)t}\ [e^{C(P - P_E)} - 1]$, where P_E is the elastic limit and A, B, and C are constants.

With particular reference to the statement of Mr. Fish that broad conclusions must not be drawn from narrow premises and that it is necessary to feel the way slowly and to await the development of soundly justified conclusions, the author wishes to state that he is in agreement with Mr. Fish on this matter, and that he knows of instances where chrome steels were advocated without sufficient investigation and with the result that due to certain amount of grain growth, brittleness appeared, causing no end of trouble and finally replacement of numerous installations. The author, however, wishes to make it clear that limiting creep stresses are not the entire solution of the problem, because we are dealing in power-plant and oil-refinery work with such other stresses as torsion, compression, etc., that must be worked out before the entire subject is brought out of its chaotic state.

With regard to Mr. Spencer's remarks as to the creep tests on chrome-nickel, chrome-tungsten, and other alloy steels, the author would say that these steels can be made up in any form, that is, rolled, forged, or cast, and that his paper did not refer particularly to valve steels but to metals for general use.

In closing, the author[8] hopes that some definite plan may be reached by which these tests may be correlated, and standardized apparatus, methods of tests, etc., be developed for future tests. He hopes, as he states in the paper, that the research laboratories and the engineers will soon meet on a common ground so that problems of this kind may be given careful consideration and future developments brought before the engineering societies.

Metallurgy has become something much greater and wider than the ancient art of extracting metals from their ores. The scientific study of metals at all stages of their existence, from the ore to the finished product, has produced a great science of metallurgy as well as an "art" that extends far beyond the reduction works and overlaps—at its other extremity—the province of the engineer. The wider definition of "metallurgy" which this growth of the subject suggests—"the science of metals and the art of their extraction, treatment, and use"—is surely a more adequate one.—*The Metallurgist* (supp. to *The Engineer*), Mar. 30, 1928, p. 34.

[7] "The Cause of Translation Striae and Translation Stain-Hardening in Crystals," A.I.M.E. Technical Publication No. 54, 1928.

[8] "Symposium on the Effect of Temperature upon Properties of Metals," Trans. A.S.M.E., vol. 46 (1924), p. 358.

The Influence of Elasticity on Gear-Tooth Loads

Progress Report No. 11 of the A.S.M.E. Special Research Committee on Strength of Gear Teeth[1]

THIS progress report is the eighth of a series of nine reports (Progress Reports Nos. 4 to 12) discussing a possible method of analysis of the test results obtained on the Lewis gear-testing machine, using the various equations developed in the previous progress reports to test their consistency, and deals with the runs made with gears of different materials.

VIII ANALYSIS OF LIMIT WEAR LOADS

The contact between gear-tooth profiles is similar in many respects to the contact between two cylinders, except that on gear-tooth profiles the radius of curvature is constantly changing. Therefore if we use the contact and pressure conditions between two cylinders as a measure of similar conditions on gear teeth, we must first establish some definite part of the gear-tooth profile as a basis of comparison.

In many cases, pitting on gear teeth, which is probably evidence of excessive compressive stresses, becomes apparent first at or near the pitch line. We shall therefore use the radius of curvature of the tooth profile at its pitch line as a basis of comparison.

The Hertz equation for the maximum specific compressive stress between two cylinders in contact under load is as follows:

$$S^2 = \frac{0.35F\ (1/r_1 + 1/r_2)}{L\ (1/E_1 + 1/E_2)} \quad \ldots\ldots\ldots\ldots\ldots [1]$$

where S = maximum specific compressive stress
F = load on cylinders in pounds
r_1, r_2 = radii of cylinders in inches
L = length of cylinders in inches, and
E_1, E_2 = moduli of elasticity of material.

For the test gears reported in Progress Report No. 10 we have the following:

$$r_1 = 3.00 \times \sin 20° = 1.026$$
$$r_2 = 8.00 \times \sin 20° = 2.736$$
$$L = 1.000$$

whence

$$S^2 = \frac{0.4690\,F}{1/E_1 + 1/E_2}$$

[1] The personnel of the A.S.M.E. Special Research Committee on the Strength of Gear Teeth is as follows:

Wilfred Lewis, *Chairman*, President, Tabor Manufacturing Company, 6225 Tacony Street, Philadelphia, Pa.

Carl G. Barth, 420 Whitney Avenue, New Haven, Conn.

Earle Buckingham, Professor, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Ralph E. Flanders, Manager, Jones & Lamson Machine Company, Springfield, Vt.

Arthur M. Greene, Jr., Dean, School of Engineering, Princeton University, Princeton, N. J.

Clarence W. Ham, Professor of Machine Design, University of Illinois, 115 Transportation Building, Urbana, Ill.

Charles H. Logue, *Secretary*, Consulting Engineer, 123 Clarke Street, Syracuse, N. Y.

Fred E. McMullen, Manager Cutter Department, The Gleason Works, Rochester, N. Y.

Edward W. Miller, Chief Engineer, Fellows Gear Shaper Company, Springfield, Vt.

Ernest Wildhaber, 1110 East 21st Street, Brooklyn, N. Y.

Table 1 gives the calculated impact loads on the tests shown in the previous progress reports where signs of distress appeared,

TABLE 1

Run No.	Material in pinion	Material in gear	Impact load, F	Maximum compressive stress, S
AB-9	Aluminum[1]	Cast iron	1129.5	57,981
AC-9	Ph. bronze[1]	Cast iron	1676.5	75,457
AD-7	Man. bronze[1]	Cast iron	1720.6	76,443
AE-9	Mach. steel[1]	Cast iron	2582.4	110,052
AG-10	Aluminum[2]	Aluminum	1130.1	54,000
AH-11	Ph. bronze	Aluminum[1]	1567.8	67,301
AI-11	Man. bronze	Aluminum[1]	1724.2	70,578
AJ-11	Mach. steel	Aluminum[1]	2027.3	87,480
AL-11	Aluminum[1]	Ph. bronze	1350.3	62,460
AM-8	Ph. bronze[1]	Ph. bronze	2645.4	93,192
AM-9	Ph. bronze[1]	Ph. bronze	2780.9	95,550
AN-11	Man. bronze[1]	Ph. bronze	2738.5	94,820
AO-10	Mach. steel	Ph. bronze[1]	1929.3	92,936
AQ-11	Aluminum[2]	Man. bronze	1269.3	60,556
AR-8	Ph. bronze[1]	Man. bronze	2552.2	91,536
AS-12	Man. bronze[1]	Man. bronze	2694.9	94,060
AT-11	Mach. steel[1]	Man. bronze[1]	2433.9	104,384
AV-8	Aluminum[1]	Cast steel	1327.1	70,778
AW-8	Ph. bronze[1]	Cast steel	2231.6	99,952
AX-10	Man. bronze	Cast steel[1]	2375.0	103,114
AY-11	Mach. steel	Cast steel[1]	2325.2	127,898
BA-46	Cast iron[1]	Cast iron	4039.2	126,016
CA-27	Semi-steel[1]	Semi-steel	2514.1	117,170

[1] Shows signs of distress.
[2] Shows abrasion.

together with the calculated values of the maximum specific compressive stresses. This table also includes runs BA and CA.

For run BA we have the following:

$$r_1 = 4.00 \times \sin 14^1/_2° = 1.0015$$
$$r_2 = 8.00 \times \sin 14^1/_2° = 2.0030$$
$$L = 1.000$$
$$E_1, E_2 = 15{,}000{,}000$$
$$\text{whence } S^2 = 3{,}931{,}500F.$$

For run CA we have the following:

$$r_1 = 2.40 \times \sin 14^1/_2° = 0.6009$$
$$r_2 = 9.60 \times \sin 14^1/_2° = 2.4036$$
$$L = 1.000$$
$$E_1, E_2 = 15{,}000{,}000$$
$$\text{whence } S^2 = 5{,}460{,}750F.$$

In Table 2 the results are grouped by materials.

Aluminum. The calculated maximum specific compressive stress on the aluminum pinion varies from about 58,000 lb. per sq. in. to about 71,000 lb., ignoring those tests where the failure was abrasion. The highest value was obtained in the run with the cast-steel gear. This may indicate the effect of increase of surface hardness due to the cold working of the material, as the cast-steel gear had the highest modulus of elasticity of any gear that the aluminum pinion engaged, and would thus compress it more. All of the other values ranged between 58,000 and 62,500, values which are remarkably consistent considering the many approximations and assumptions which were necessary to complete this method of analysis.

The values on the aluminum gear ranged from about 67,000 to about 87,500. The highest value here also occurred when running with a steel pinion, which is consistent in nature with the results on the aluminum pinion. The results when running with bronze pinions are almost identical.

TABLE 2

Run No.	Maximum compressive stress, *S*	Member showing distress
	Aluminum	
AB-9	57,981	Pinion
AG-10	54,000[1]	Pinion
AH-11	67,301	Gear
AI-11	70,578	Gear
AJ-11	87,480	Gear
AL-11	62,460	Pinion
AQ-11	60,556[1]	Pinion
AV-8	70,778	Pinion
	Phosphor Bronze	
AC-9	75,457	Pinion
AM-8	93,192	Pinion
AM-9	95,550	Pinion
AO-10	92,936	Gear
AR-8	91,536	Pinion
AW-8	99,952	Pinion
	Manganese Bronze	
AD-7	76,443	Pinion
AN-11	94,820	Pinion
AS-12	94,060	Pinion
AT-11	104,384	Gear
	Cast Steel	
AX-10	103,114	Gear
AY-11	127,898	Gear
	Machine Steel	
AE-9	110,052	Pinion
AO-10	92,936	Pinion
AT-11	104,384	Pinion
	Cast Iron	
BA-46	126,016	Pinion
CA-27	117,170	Pinion

[1] Abrasion.

Phosphor Bronze. The values on the phosphor-bronze pinion vary from about 75,500 to 100,000. The highest value here also occurs when the pinion meshes with the cast-steel gear. The lowest value was given by the run with the cast-iron gear. Excluding these two extremes, the values ranged from about 91,500 to 95,500, which are very consistent.

The phosphor-bronze gear showed signs of distress only when running with the steel pinion. In this case the steel pinion also showed signs of distress. The value in this case was about 93,000.

Manganese Bronze. The values on the manganese-bronze pinion vary from about 76,500 to about 95,000. The lowest value was also given by the run with the cast-iron gear. The other two values are practically identical. When running with the cast-steel gear the gear showed signs of distress with a value of about 103,000, while the bronze pinion was not affected.

Cast Steel. The cast-steel gear showed signs of distress when running with the manganese-bronze pinion and the machine-steel pinion. The calculated values of the maximum specific compressive stresses were about 103,000 and 128,000 lb. per sq. in., respectively.

Machine Steel. The values on the machine-steel pinion vary from about 93,000 to about 110,000, which are quite consistent.

Cast Iron. The value for the cast-iron pinion was about 126,000, while that for the semi-steel pinion was about 117,000. This may indicate that the compressive strength of the semi-steel is not quite as high as that for cast iron. The values are reasonably close to each other, however, and many more tests with a greater variety of test gears are required before any definite conclusion on this matter can be drawn.

In general, these values are slightly greater than the probable compressive strengths of the materials. This agrees with other tests of the compressive strength of materials where impact tests usually give about 30 per cent greater values than static tests.

It would appear from the analyses of the test results that the tentative equations used throughout give a very close approximation to the actual conditions present on gear teeth under load. It is proposed to obtain further confirmation of this by making a series of runs at pitch-line velocities varying from about 3000 ft. per min. down to about 200 ft. per min. and measuring the applied load that causes the first signs of distress to appear. If the maximum specific compressive stresses as calculated from the impact loads prove to be consistent with each other and the probable compressive strength of the materials, these tests should be about as conclusive as any we can make with the facilities now available. In addition, such data would enable reliable limit wear loads to be established.

An Improved Brickmaking Plant

IN THE new brickmaking plant of the Danville Brick Co., Danville, Ill., two features of particular interest are the burning system and the waste-heat drier. Especially worth while is the fan system used to aid in burning and cooling. About 20,000 brick more can be burned daily with the same kiln capacity than was possible prior to the installation of the fans. At the very beginning of the burn, when the watersmoke is heavy and the draft sluggish, a number $3^1/_2$ Garden City portable fan is set at the base of the stack with a sheet-metal pipe running into and a few feet up the stack. For the first twenty-four to thirty-six hours this fan is kept going, creating what is virtually an induced-draft system. There are six of these fans in use in the plant.

This system speeds up the watersmoking period considerably by pulling the moisture out of the kiln practically as fast as it is formed. The removing of the watersmoke means that humidity in the kiln is greatly reduced and breaking and cracking of brick from this cause is lessened.

Prior to the installation of this system a different method was employed which also used a fan at the base of the stack, but in this case gases were pulled directly through the fan and discharged into the atmosphere. Besides increasing the dirt, soot, and smoke about the yard, it was found that passing the gases through the fan was very hard on the equipment, the sulphur and other acid gases attacking the metal and corroding it beyond usefulness in a comparatively short time. With the system now in use no kiln gases pass through the fan, the draft being created by induction or a vacuum.

After the watersmoking is over and heavy firing begins, a portable Ilg fan used for furnishing pressure for the forced-draft system is put on and kept there for the remaining part of the burn. There are 15 of these fans in use on the plant, one fan being used for every kiln on fire.

The kilns are provided with an 8-in.-tile flue which runs around the entire circumference, under the fire boxes. This main flue is tapped at each firebox with a 4-in. flue. The forced-draft system provides a positive, controlled air supply to the fireboxes, making it possible to burn a very low grade of coal, almost a slack, which is claimed to be partly responsible for the peculiar and distinctive shades of brick obtained.

A temperature of 1800 to 1900 deg. fahr. is obtained in the kilns, depending upon the kind of brick desired. The burning time also varies considerably, only 4 days being required to burn clear reds, while 7 days are needed if some of the darker shades and purples are desired. While this burning time may seem long to some manufacturers, it must be remembered that high-carbon shale must be burned very slowly. (*Brick and Clay Record*, vol. 72, no. 3, Jan. 31, 1928, pp. 199–201, *d*)

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Modern Theories of Lubrication

THE author reviews modern developments in the theory of lubrication and considers in the first place the relation between the surface tension and lubrication. He points out that in lubricants the form of meniscus is such as to cause the lubricant to penetrate into the most restricted spaces. On the other hand, a number of viscous liquids such as molasses and cellulose washes have no lubricating value because of their excessively high surface tension. Similarly, coal-tar oils and particularly anthracene oils have less efficiency as lubricants than fatty or mineral oils because they form on the metallic surface what one might call "flakes." A determined effect has been made by various investigators to measure all these properties and derive the necessary laws. The work of Dallwitz Wegener is particularly important in this connection, as he made an effort to measure the surface tension at the oil-metal border. Directly, this cannot be done, but Mr. Wegener has determined the relation indirectly by measuring the surface-tension phenomena between oil and water. The author cites a number of investigators, and the result of all of their investigations is the conclusion that with respect to water the tension of vegetable and animal oils is much lower than that of mineral oils. The former, however, possess to a high degree the still somewhat mysterious property of "oiliness," and it would appear that high oiliness is accompanied by low oil-to-water tension. It was furthermore found that the low interfacial tension between fatty oils and water is due to the low content of free fatty acids in the former. When fatty acids are taken out of the fatty oils an increase in tension is noticed, and when free fatty acids are added the tension is lowered and the oiliness improved. All commercial vegetable and animal oils contain small quantities of free fatty acids, and even when an effort is made to eliminate these acids by a refining process the oils immediately undergo a process of hydrolysis which produces these acids in a quantity very small but still sufficient to reduce the surface tension.

Surface-Tension Phenomena

It would appear from this that in the first place capillary effects which hitherto have been completely ignored in connection with lubrication play an important part therein. Next, the presence of fatty acids in an oil decreases the surface tension of this oil with respect to water, and finally the addition of even a very small amount of fatty acid to a neutral mineral oil brings its tension to that of an animal or vegetable oil of the kind that is employed in lubrication.

There is, of course, one serious objection to such conclusions as have been brought out previously, and that is that the interfacial tension between oil and water may be different from that between oil and metal. This objection has been in part removed by a study of tension between oil and mercury (Lewis) where it was shown that in this case the tension also decreases with an increase in content of free fatty acids.

The question is still open, however, as to why it is that vegetable or animal oils or oils containing fatty acids have a lower surface tension and a higher oiliness. The latest work of Langmuir, Woog, and the author himself in this direction is supposed to give an answer to this question.

The Molecular Concept

The "power to spread" of lubricating oils may be considered as both a chemical and a physical phenomenon, due probably to a residual valence. Langmuir has investigated the spreading of fatty acids and triglycerides over water and his findings led him to establish the basis of a chemical theory of capillarity. According to this theory, surface tension is due to a residual affinity which causes the molecules of the surface layer to orient in certain definite directions, and it is the structure of the surface layer of atoms that is considered as being the principal factor in determining the magnitude of the surface tension or of the surface energy of the liquid.

According to this theory the molecules in the surface layer are so located that their active parts, which means those which possess most of the residual activity, are directed outward, while the least active parts of the molecule form the surface layer. The chemical action may be then assumed to be due to the magnetic field surrounding the atoms. The surface energy of the liquid is therefore not a property of the molecule considered as a whole; it depends only on the least active parts of this molecule and the manner in which they are disposed in the surface layer. In the liquid carbon derivatives of the fatty series the molecules are so disposed that the methyl groups (CH_3) of the ends of the chain form the surface layer. This latter will be therefore the same no matter what the chain may be, and experimentally it has been found that the surface energy is the same in all the substances from hexane to molten paraffin, notwithstanding the notable difference in the molecular weights of the substances. Substantially the same surface energy was found in the case of alcohols as in the hydrocarbons, a fact which can be easily explained by supposing that the hydroxyl groups (OH) are directed toward the interior of the liquid while the groups (CH_3) constitute the surface.

Numerous investigations by Lord Rayleigh, Marcelin, Devaux, Woog, and others on very fine layers of oil on water confirm this theory of capillarity, and the author refers particularly to experiments with oleic acid (compare in this connection Mechanical Engineering, vol. 49, no. 9, Sept., 1927, p. 1019). From all of this material it would appear that the spreading of oil over water is due to the presence in the molecule of an active group, and by active groups are here understood double (carbon) compounds CO OH, COR, NH_2, CN, NO_2. Hence, if an oil is lacking in these active centers as is the case of saturated carbon mineral oils, it will not spread over water, and experience has confirmed this supposition. It would appear, therefore, that there must be a chemical action in order that a fluid should spread in the form of a very thin layer between two other fluids. Furthermore, the mechanism of spreading of oleic acid would indicate that the acid molecules are oriented, the carboxyl groups being immersed in water, while the hydrocarbon chain holds itself vertical above the surface of the water. From Langmuir's

calculations of the dimensions of molecules it would appear that the molecules of fatty acids, carbides, and triglycerides are very much elongated, the length of the molecule of palmetic acid being, for example, 5.2 times its average diameter. Because of this the molecules along the surface take such a position that their major axis is vertical (which is in accordance with the theory); in other words, they take the position along the surface of the water, looking like fishermen's floats.

The next question is to determine to what extent the spreading of oils over metals follows the same apparent laws established for oil and water by Langmuir, Woog, and others. This work has been carried out by Woog and the present author.

Woog has shown that when oil is applied to solid surfaces the movement of the marginal molecules of the drops is not as free as in the case of liquid surfaces, and as soon as the zone of oriented molecules is formed at the edge of the drops it acts as a kind of a barrier anchored to the solid body and thereby completely modifies the course of the phenomenon. Furthermore, here the active centers act primarily by their mutual attraction, which is not counterbalanced by the attraction of the surfaces as these are neutralized by the presence of the border or oriented molecules. An apparently greater cohesion of active oils is therefore found, and the phenomena, although due to the same causes take an entirely different aspect from those found when dealing with water instead of a metal. If drops of oils of approximately the same viscosity but different activity are deposited on steel or brass plates held horizontally, it will be found that no matter what may be the character of the supporting medium, there occurs a rapid coverage of the entire surface if the oil contains only saturated molecules. An oil containing a mixture of saturated and unsaturated molecules undergoes a much slower extension, while drops of vegetable and animal oils retain their shape and do not show any tendency toward expansion. From the point of view of energy of motion the nature of the support seems to play an important part, the phenomena of spreading being more intensive with steel than with brass. If now small quantities of active molecules are added to an inactive oil (and fatty acids are not the only ones that produce active molecules) it is found that at first the drops expand into a fairly large disk, then they contract into tiny pools and become stable as such. This may be explained by assuming that the reciprocal attraction of the active groups determines the contraction of the liquid masses *as soon as* the field of attraction emanating from the solids has become neutralized as a result of the coverage of the solids by the oils.

In this way a condition is artificially created where the oil held and is given qualities analogous to fatty oils and particularly qualities of oiliness. A new factor, however, appears from these tests which has not been referred to before, and that is adherence of the oils to the metallic surfaces. This adherence may be explained by molecular considerations of affinity and particularly of activity, and would therefore be substantially of electromagnetic origin. In accordance with what has been said above, molecules producing only a feeble field, as, for example, saturated oils, will adhere poorly, while molecules having a powerful molecular field, as for example, the glycerides in fatty oils, are capable of strong attachment to metallic surfaces.

The next step is to study the manner in which oil molecules are distributed over solid surfaces which they are supposed to lubricate. It is known already that at the place of contact with metal these molecules are oriented, at least those which are endowed with sufficient activity. The only question is as to the structure of this infinitely thin skin which is capable of resisting enormous pressures without rupturing and facilitates the sliding of metallic pieces one over the other. Very ingenious experiments were carried out, particularly by Woog, with the view to solving this problem. These experiments dealt with the resistance of the contact layers, the phenomena of adsorption by screens, viscosity, and measurement of friction in the oily phase. The most interesting series of experiments was carried out in the study of lubrication by X-rays.

X-Ray Investigation of Lubrication

By X-ray investigation, using the method of rotating crystals, the author claims to have found that when a fatty acid being solid or liquid is deposited on a metal plate, in addition to the spectra of the border of the excess acid where it is solid, a spectrum is obtained characterizing the way in which the metal is attacked by the acid; and the original paper shows a number of such spectra, from which it would appear that the attack of the fatty acid on a metal takes place by way of formation of a very thin layer, invisible for the most part, and that this layer is endowed with a perfectly stratified structure resembling in a way that of a pack of playing cards. The CO OH parts take root in the metal, and the molecules having thus obtained a solid base, assume a parallel orientation by grouping their extremities in equidistant intersecting planes. Exactly the same phenomenon takes place in the case of a mineral oil in which free acid is present or an oil in which a fatty acid has been dissolved. The molecules of the acid, very active and endowed with a marked affinity for the metal, are attracted to the surface of the latter, become oriented there and "take root," forming a certain number of superimposed "leaflets" of the same thickness. The metal surface is thus supplanted by another surface externally covered with CH_3; the intense electromagnetic field of the metal is thus partly neutralized and replaced by a much weaker field emanating from the terminals of the CH_3, as a result of which the friction due to molecular attraction is found to be reduced. The hydrocarbon molecules slide with great ease over this new surface, which in addition possesses the following property: The leaflets of the lubricant thus formed slide very easily over each other with little or no friction, while they resist deformations in any other direction. This is practically the same as in the case of a pack of cards. The affinity of the fatty acid for the surface of the metal offers an explanation of the stability of an oil skin. But fatty acids are not the only bodies capable of powerful orientation when in contact with the surface of a metal, and the author found that this holds true for triglycerides, excepting that with these it is not chemical affinity but a physical affinity which causes adhesion. The molecule of these bodies (i.e. triglycerides) is somewhat similar to a three-compartment suitcase, the active part corresponding to the glyceric radical. It is this part that becomes attached to the metal supporting body, whereupon the free chains arrange themselves vertically. A second molecule places itself opposite to the first, but back to back, so that the elementary leaflet comprises two molecules. The CH_3 planes are the planes of easy gliding, while the methyl terminals are endowed with a very low activity. Under the least tangential effort along these planes easy gliding or cleaving will take place, and it is this which gives to the substances their greasy feeling when touched. It is in the same structure likewise that one may look for the origin of oiliness. [Oiliness in so far as X-ray investigations have shown hitherto, would appear to be primarily the ease with which bodies can become oriented and take a stratified or laminar structure of the kind described above.]

The next question is whether oiliness is a permanent property of a given substance or has been created accidentally and through outside influences.

The author describes in some detail experiments undertaken to provide an answer to this question. The conclusion to which he comes is that oiliness is a latent property brought out by such

external physical agencies as pressure or friction: substantially, the old method of testing the oiliness of an oil by rubbing some of it between the finger and the palm of the hand is an excellent proof thereof.

Notwithstanding the very considerable difficulties of experimentation, the author has been able to apply these results to a number of other bodies and, for example, has definitely found a stratification in such liquid component bodies as oleic acid when pressed between two sheets of glass or metal. It is important, however, to observe that it seems that all molecules so long as they are sufficiently dissymmetric are capable of acquiring orientation under pressure and in certain cases also to become arranged in parallel leaflets, this happening every time that a thin layer of oil is compressed between movable pieces. Moreover this phenomenon is not limited to lubricating oils, and X-rays indicate its presence in the rolling of metal in the structure of drawn rubber or glass, etc. Every time sufficiently dissymmetric molecules are present in a fluid mass subject to violent tension or pressure effects, these molecules react by way of a more or less perfect orientation. Both with inactive and active molecules this phenomenon of orientation followed by stratification under pressure appears to be common to lubricating oils. The presence of active molecules, however, increases its effectiveness enormously and is furthermore accompanied by a phenomenon of adherence to, or more exactly, adsorption on, the surface of the metals, thus creating a layer of oil endowed with special qualities which, properly speaking, characterize oiliness.

In mixtures of active and inactive molecules the former are selectively adsorbed through the intensity of the molecular field which they cause to eliminate or of the affinity which they have for the metal. The fact that spectra of several kinds of mixed molecules may be observed proves that the stratification resulting therefrom is not a simple one but of a sufficiently complex nature. The author therefore offers a hypothesis in accordance with which, under the influence of pressure, molecules react in creating an opposition to this pressure and in effecting a mutual orientation. By placing themselves perpendicularly to the metallic surfaces they neutralize the molecular field emanating from the latter; they therefore have a tendency to occupy a certain direction, and, what is more, to group themselves parallel to each other so as to make the total energy a minimum. They will therefore stand up side by side, selectively forming a series of molecular ranks. The orientation should not be limited actually to an alignment of molecules in a single layer, because the extremities of these molecules directed toward the liquid also create a field of force, though the latter are more feeble and inferior to those emanating from the solid body. Because of its regularity, however, the terminal field of force of the first row is sufficient to cause an orientation of a second group of molecules, and so on. In the case of acids and triglycerides which are asymmetric the leaflets thus formed are bimolecular and their adherence is greater because of the greater value of the field radiated therefrom. (*Modern Theories of Lubrication*, by J. J. Trillat, Doctor of Science, 7 pp., 8 figs. The complete French original is available in the files of The American Society of Mechanical Engineers, *tA*)

Short Abstracts of the Month

AERONAUTICS

A 100-Ton Floating Dry Dock for Flying Boats

TOWARD the end of last year there was successfully launched from the yard of Flewder Werken, at Lübeck, a 100-ton floating dry dock for the flying boats on the Lübeck-Travemünde service of the Deutsche Luft Hansa A.G. It is believed that this dock is the first of its type to be built.

The dock comprises two parts, the forward part, which is left free to receive the flying boat or seaplane that it is desired to dry dock, and the after part, on either side of which the workshops, machinery rooms, and staff accommodations are arranged. The usual moving bollards are fitted, and on either side of the dock is a derrick post and crane jib with lifting appliances for 4 and 2 tons. At the center of the dock rails are laid to take the wheels of a trolley, by the use of which the machine may be quickly transferred from the dock to the sheds. The following general method is followed in dry docking the machines: Before being anchored the dry dock is maneuvered into such a position—against the wind—that the flying boat can easily alight upon it. Before the machine actually alights the dock is submerged, and as soon as the boat is over the forward free part it is pumped out, and the machine is raised clear of the water for examination of the under parts. When further repairs are necessary the flying boat is hauled into the sheds of the trolley. We are informed by the owners of the dock that it was launched from the builder's yard without difficulty, that it has proved satisfactory in service, and that the design has met all requirements. It is pointed out, however, that it may be expected that both the designers and the builders will be able to suggest still further improvements, which will prove useful to the growing development of sea flight. (*The Engineer*, vol. 145, no. 3767, Mar. 23, 1928, p. 320, *d*)

ENGINEERING MATERIALS (See also Machine Tools: Extra High-Speed Lathe and "Widia" Cutting Metal)

"Egalite" Aluminum Alloy

THIS is a material manufactured by the Egal Metal Products Co. of Baltimore, Md. It is subjected to a special process while in the molten state, and it is claimed that thereby a greater uniformity of molecular structure is obtained. The special process used is not explained, and no data showing a comparison of properties of ordinary aluminum alloys with the special one described here are given. Such figures as are quoted in the article deal with the comparison between cast iron and Egalite alloy. (P. M. Heldt in *Automotive Industries*, vol. 58, no. 10, Mar. 10, 1928, pp. 416–417, *g*)

FUELS AND FIRING

Oil-Engine Performance on Coal Oils

DATA of test carried out on a 35-b.hp. Mirrlees-Diesel oil engine with fuel oils derived from certain low-temperature processes of coal carbonization, particularly from the Glasgow Corporation Maclaurin plant and the "L. & N." oil from the Barnsley plant, as well as "Turner" oil, which is a crude product from the plant at Lesmahagow in which the heating is supplied by the direct entry of superheated steam into the retort. (For a description of the Maclaurin and "L. & N." processes see respectively, MECHANICAL ENGINEERING, vol. 47, no. 2, Feb., 1925, p. 126, and vol. 49, no. 5, May, 1927, p. 459.)

At full power, two of the new oils, the "Turner" and the "L. & N.," gave satisfactory and complete records, but in the case of the "Maclaurin" oil the extreme viscosity caused the fuel pump to lose its suction a short time after changing over from petroleum oil on which the engine had been first run up. Possibly, the author states, the oil could have been handled quite well in a heated condition, but such a modification was regarded to be outside the scope of the immediate tests. Attention may be called to variations in fuel consumption which practically dis-

appear when the calorific values of the different oils are adjusted to a common basis of 18,500 B.t.u. per lb.

Only in the case of the "Turner" oil was it possible to avoid preignition when the engine was running at no load. As this condition is readily satisfied by the petroleum oils, it becomes evident, the author says, that the low-temperature-carbonization oils tend to be deficient in their ignition qualities. In the case of the "L. & N." oil, the misfiring disappeared with quite a small load on the engine, and that oil might therefore meet all practical requirements. With the Bedlay coke-oven oil, misfiring was very violent at 20 b.hp., and the lowest useful output was about 24 b.hp.

The starting tests showed that none of the oils possesses the qualities shown by a petroleum oil in enabling the engine to be got under way with cold jackets, but preheating of the jackets to the normal working temperature gave satisfactory starting qualities with both the "Turner" and the "L. & N." oils.

The general conclusion to be drawn from the tests described is, the author states, that the oils obtained by the low-temperature carbonization of coal provide a Diesel-engine fuel which is distinctly in advance of the tar oils. But there is still a slight handicap in comparison with the petroleum oils, due to a deficiency in the ignition qualities of the new oils when used with the standard injection arrangements on a Diesel engine. This defect causes the operation of the engine at low powers to be somewhat critical, and also necessitates the adoption of special starting arrangements. (J. S. Brown in a paper in the *Journal of the Royal Technical College*, Glasgow, abstracted through *The Engineer*, vol. 145, no. 3765, Mar. 9, 1928, p. 274, *e*)

HYDRAULIC ENGINEERING

The Defour Tidal Power Scheme

IT IS SAID that this system has reached the stage where there is a possibility of its being realized at a comparatively early date. Two installations in France are now in project. In one at Le Crotoy, where the difference between high and low tides is 10 m. (32.8 ft.), the cost of installation, it is claimed, will be about 30,000,000 francs (say, $1,500,000) for a production of 10,000 hp.

The essential feature of the Defour system is the construction of a dam across a narrow part of a bay, and, at right angles to it, another dam extending to the shore, which divides the bay so enclosed into two basins, one having double the area of the other. The smaller reservoir is called the main basin, because it works approximately for about three-fourths of the time, the auxiliary basin, which drives the turbines by a discharge into the sea, being employed to come to assist it. Where the dividing dam joins the main dam it forks out into two branches to each side of the turbine galleries. The fork constitutes the turbine race and has sluice gates putting one or the other basin into communication with the turbines. On each side of the turbine galleries are sluice gates putting the basins directly into communication with the sea. Farther out, the bay is enclosed by a breakwater with oblique openings which divert currents and prevent heavy swells inside. The breakwater consists simply of blocks of concrete and rocks.

One of the problems involved in the design of tidal power plants is to supply a quantity of energy corresponding with the varying load, particularly in the course of 24 hr. In the Defour system the auxiliary basin which only drives the turbines on a discharge into the sea takes over the work when the head from the principal basin falls too low. There is thus a fairly regular output during the whole period, but this does not provide for peak loads. Defour solves the problem by varying the relative levels of the two basins. The auxiliary basin is emptied to the level of the lowest tides, and the level can be regulated as required. In the same way a filling of the principal basin may begin when this level is sufficiently below the level of the auxiliary basin to provide the head of water required to meet the load. Thus by adjusting the levels of the two basins in relation to the sea level, it is possible to utilize the energy of one basin at the expense of the other in order to meet the peak loads.

The working of a Defour tidal power station depends upon what appears to be a complicated manipulation of sluice gates, which have to be opened and closed at various times in relation to each group of sluices, but it is declared that the operation is simple and automatic. The mechanical arrangement consists in floats on each side of the gates which act through differential pulleys and bellcranks and switch on the electric motor as soon as they are in predetermined positions relatively to each other. Those positions can be adjusted by a displacement of the differential pulleys. There are other ways of opening and closing the gates, and whichever is finally adopted it appears that the gates can be manipulated by one man, who sets the gears according to the difference between the sea and basin levels at which the gates are to be opened and closed.

This account of what is being done in France shows that the problem of drawing energy from the tides is being worked out on a rational basis. So far as theoretical considerations go, the schemes are proving attractive to big electrical and mechanical engineering corporations, which see in this new branch of experiment a considerable opening for industrial activity. (*The Engineer*, vol. 145, no. 3767, Mar. 23, 1928, pp. 326–327, 4 figs., *d*)

INTERNAL-COMBUSTION ENGINEERING (See also Fuels and Firing: Oil-Engine Performance on Coal Oils; Mechanics: The Kinematics of the Andreau Differential-Stroke Engine; Railroad Engineering: Diesel Engines for Railroad Traction)

The Winton High-Speed Airless-Injection Diesel Engine

THE six-cylinder four-cycle unit of this type with 8-in. bore and 10-in. stroke developing 200 hp. at 700 r.p.m. was designed primarily for use on yachts and work boats. Certain refinements of design may be of general interest. All control levers of the engine as well as the instrument board with gages are located at the front end. All working parts are accessible and are lubricated by pressure feed. Fuel is fed directly from the main fuel tank through a three-cylinder plunger-type pump into the fuel manifold, and from there is injected under pressure into the cylinder through a special needle-type injection valve which is camshaft operated.

The rocker arms are chrome-nickel-steel drop forgings, bronze bushed, operating on top of the cylinder heads by push rods from the camshaft. Each push-rod end is equipped with a hardened carbon steel ball, and the valve end is equipped with hardened steel rollers and pins.

The push rods are made of seamless nickel-carbon unannealed steel tubing. The top end is a hardened steel socket to receive the ball at the end of the rocker arm; while the lower end is fitted with a hardened steel bottom seated in a roller plug, actuated by a cam. A high-carbon built-up camshaft is fitted with six cams, one exhaust, one intake, and one fuel injection for go-ahead, and one exhaust, one intake, and one fuel injection for reverse. All cams are of molybdenum steel, drop forged and hardened, held to shaft by taper pins.

A reversible, duplex-gear-type lubricating pump on the pressure side forces oil from the supply or filter tank to the main lubricating-oil header; the scavenging side forces oil from the

crankcase sump through a cooler to the filter tank. (*Motorship*, vol. 13, no. 3, March, 1928, pp. 228–229, illustrated, *d*)

Supercharging Diesel Engines

DESCRIPTION of what is claimed to be a new method of supercharging. The plant (Fig. 1) comprises a blower *A*, cooler *B*, expansion nozzle *C*, and reservoir *D*, which latter, in a multi-cylinder engine, will be the induction manifold. The only addition to the usual supercharging arrangement is the expansion nozzle *C*.

First, let it be assumed that the engine is to be supercharged with 10 per cent additional air in order to burn 10 per cent additional fuel. The induction pressure will therefore have to be raised from atmospheric pressure to 16.2 lb. per sq. in. abs. pressure, i.e., a gage pressure of $1^1/_2$ lb. per sq. in. Further,

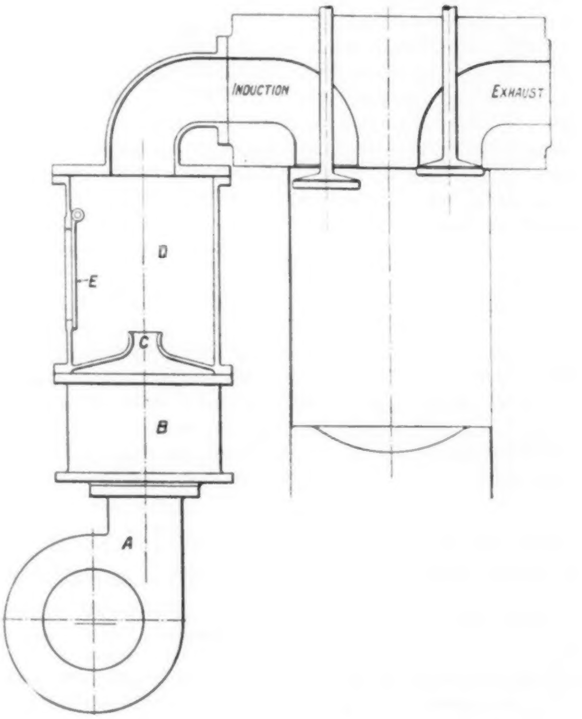

FIG. 1 PROPOSED METHOD OF SUPERCHARGING WITH EXPANSION NOZZLE IN THE AIR RESERVOIR

assume the temperature of the engine room to be 80 deg. fahr., and the air leaving the cooler to be also reduced to 80 deg. fahr.

This represents an absolute temperature of 460 deg. fahr. + 80 deg. fahr. = 540 deg. fahr. This air on reexpansion to atmospheric pressure through the nozzle *C* will have its temperature reduced to $(540 \times 14.7)/16.2 = 490$ deg. abs., the temperature after reexpansion becoming 30 deg. fahr., and the pressure being atmospheric but containing the same weight of air per cubic foot as was contained per cubic foot when its temperature was 80 deg. fahr. and its pressure $1^1/_2$ lb. gage.

This air is then introduced to the engine cylinder through the usual air-induction valve, and at the end of the induction stroke the engine will be supercharged by 10 per cent additional weight of air at atmospheric pressure, but at a temperature much below the temperature of the air in the engine room. The compression pressure will now be the same as when the engine was started up under non-supercharging conditions, but as the engine will now be warm, the compressed air in the combustion space will still have sufficient temperature to insure satisfactory ignition of the fuel.

This new method of supercharging offers distinct advantages in allowing large cylinder units to carry high indicated mean pressures with an increase of reliability and freedom from trouble with liners, pistons, covers, and exhaust valves. It will of course be necessary to lag the cooled-air reservoir and induction piping with non-conducting material in order for the induction air to pick up the minimum possible amount of heat from the engine room between leaving the expansion nozzle and its introduction into the cylinder. The valve *E* on the reservoir *D* is opened at starting and whenever it is required to run without the supercharging blower in action, in order to allow the engine, when running, to draw air from the atmosphere, and is kept closed when supercharged. It will of course be appreciated that the new method entails a loss of $1^1/_2$ lb. per sq. in. during the suction stroke in the example taken, but it is anticipated that the expansion line will be 5 to 6 lb. per sq. in. higher throughout, owing to the reduced jacket losses following on the reduction in temperature head between the combustion gases and the cooling water, leaving a net gain in mean pressure and thermal efficiency of 3 to 5 per cent.

It does not appear that an engine employing this method has actually been built. (*Marine Engineer and Motorship Builder*, vol. 51, no. 607, Jan., 1928, pp. 103–104, 1 fig., *d*)

A Five-Stage Internal-Combustion-Engine Cycle

IT IS ONE of the fundamental differences between the steam engine and the internal-combustion engine that whereas in the former the working cylinder is carefully lagged with a heat-insulating material, in the latter special means must be provided for cooling the cylinder, and in large engines the piston also. The reason for this is of course that in the steam engine the average working temperature is sufficiently moderate for the materials of which the cylinder and the piston are made to withstand its effect; hence we endeavor to prevent the loss of heat due to conduction by insulating the cylinder. In the internal-combustion engine, on the other hand, the average temperature in the cylinder is so high that were not adequate means taken to maintain the cylinder walls and the other parts adjacent to the combustion space at a far lower temperature, seizure of the piston in the cylinder would occur and the materials would fail as a result of the stresses induced by the high temperature. This cooling of an internal-combustion engine is responsible for the absorption of about 30 per cent of the heat generated in the cylinder.

If some means could be devised whereby the necessity for cooling the cylinder and piston of an internal-combustion engine could be obviated, a far higher thermal efficiency would be possible. Many investigators have directed their attention to this problem, but it has been left to a young engineer from New Zealand to develop a cycle of operations which can be applied to existing designs of engine and by means of which the use of external cooling is entirely eliminated. The fundamental idea is the use of a "five-stage" cycle differing from the familiar four-stage cycle, i.e., suction, compression, combustion and expansion, and exhaust, in that what is termed "a refrigerating stage" is introduced after the suction stage. It is to be noted, however, that the complete cycle is still operated in four strokes of the piston. Briefly, the suction of air occurs through a specially designed valve which is closed after the piston has completed about one-half of its suction stroke. During the remainder of the stroke the piston, in moving forward, causes the pressure of the air to fall to about 10 lb. per sq. in. below atmospheric, this being accompanied by a corresponding fall of temperature. Owing to a swirling motion of the air which is imparted to it during its passage through the valve, the cylinder walls are cooled sufficiently to obviate the necessity for any external cooling, the heat

thus absorbed from the cylinder walls being retained in the cylinder, hence the use of the term "refrigerating stage." The remainder of the cycle follows along the conventional lines, except that the compression ratio is of necessity higher in order to obtain the requisite pressure at the end of the compression stroke.

An experimental engine has been constructed in which this cycle is employed, and it is said that the fuel consumption is 50 per cent less than that in a similar engine working in the usual four-stroke cycle. The engine of a Ford car has also been modified to operate on the five-stage cycle, and the car is said to run from 30 to 60 miles to a gallon of gasoline on all sorts of roads in New Zealand. (Editorial in *Power Engineer*, vol. 23, no. 265, Apr., 1928, pp. 121–122, *td*)

MACHINE PARTS

The Rieseler Hydromechanical Reduction Gear

THIS gear has been submitted to exhaustive series of tests in Germany which have shown that the power transmitted has very little effect upon the efficiency and that the general efficiency of the gear is high. The gear was applied to a Mercedes car driven at various speeds.

The method by which the gear operates can best be followed by reference to the diagram, Fig. 2. It largely depends on the employment of three control brakes. These brakes and the clutches are operated by oil under pressure, which is supplied by a pump driven from the engine camshaft. At starting, when the engine is running freely at low speed, the speed of the pump is not sufficient to cause any pressure to be generated. The position of the various devices is then as follows: The disk clutch *F* on the engine shaft is disengaged, brake *E*, on the turbine is on, brake *L*, which controls the forward gearing is off, brake *P*, which controls the reverse gearing is on, and clutch *Q* is disengaged. As the engine is accelerated and the pump pressure increases, the vehicle starts quite smoothly, both hydraulic and mechanical gears being in action and the gear ratio being a maximum.

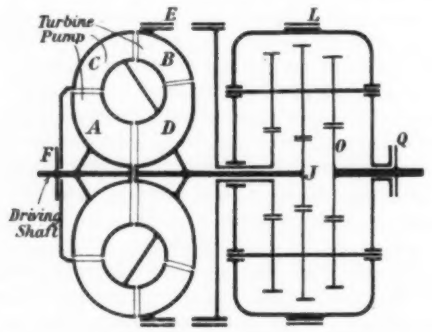

FIG. 2 GENERAL DIAGRAM OF THE RIESELER HYDROMECHANICAL REDUCTION GEAR

The gear can then be changed by moving the control cock on the steering column to its first operating position, and thus opening the control valve *T*. This releases brake *E*, clutch *F* remaining in engagement. The turbine and engine shafts are therefore coupled together, and the pump, turbine, guide blades, and turbine housing are caused to revolve with the primary shaft. The mechanical gear is now solely in action, and the second forward speed is obtained in this way. The transition from one speed to the other is effected without shock, as clutch *F* engages gradually.

A further movement of the control cock releases brake *P* and brings clutch *Q* into engagement. This cuts out the mechanical gearing, the housing containing it being run at full speed and driving the propeller shaft directly through clutch *Q*. This change-over is also affected gradually.

When the vehicle is standing on the level, and it is therefore possible for the direct drive to be brought into action sooner, the operations described in the preceding paragraphs can be still further simplified.

Fig. 3 shows the power received by the oil pump used for operating the gear at different outputs and engine speeds. As will be seen, so long as the engine speed is low, the pump does not begin to operate, and the vehicle will remain stationary, even after the hand brake has been released. As the engine speed is increased, the pump input also increases, as does the output of the turbine, the change taking effect as the cube of the engine speed. The vehicle therefore starts smoothly with a very high torque, and rapidly attains speed at which the direct drive can be used.

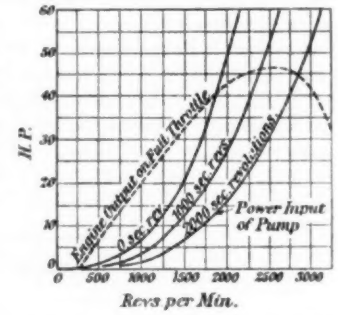

FIG. 3 CURVES SHOWING POWER RECEIVED BY THE OIL PUMP OF THE RIESELER HYDROMECHANICAL REDUCTION GEAR

The fact that it is possible to start without cutting off the power from the engine, and even without throttling down, is, it is claimed, of great importance from the point of view both of manipulation and acceleration. The latter is, of course, high, owing to the fact that the starting torque of the Rieseler gear is some 40 per cent greater than that of ordinary mechanical gearing. (*Engineering*, vol. 125, no. 3248, Apr. 13, 1928, pp. 444–445, 10 figs., *d*)

MACHINE SHOP (See also Machine Tools: Extra High-Speed Lathe and "Widia" Cutting Metal)

Machine Arrangement in the Continental Motors Corporation Shops

THE particular feature in the production line-up here described is the machine arrangement employed whereby output can be varied within rather large limits without affecting to any considerable degree the efficiency of the work.

As shown in an illustration in the original article, the primary machine line-up consists of two parallel rows of machine tools separated by a sheet-steel-topped table extending the length of the aisle which serves as both a repository for pieces in process and also as a sort of conveyor along which crankshafts are slid from one operation to the next.

At frequent intervals passageways from one machine to the other are provided, but with these exceptions the steel-topped table is continuous. Machine tools are generally arranged in pairs on either side of the table. If two machines are required to meet maximum output on one operation, they will be placed opposite each other, one in each row. When more machines are required they are arranged in the same general manner. When the production program calls for less than maximum output it becomes a simple matter to cut one or more duplicate machines out without leaving any wide gaps in the line or making it any more difficult to pass the work from one operation to the next. The remainder of the article gives the details of operation on the crankshaft. (K. W. Stillman in *Automotive Industries*, vol. 58, no. 11, Mar. 17, 1928, pp. 444–445, 2 illustr., *d*)

MACHINE TOOLS

An Extra High-Speed Lathe and "Widia" Cutting Metal

THE Fried. Krupp Co. at Essen is making a new cutting metal which they call "Widia." Its composition is not known, but it is known that it is supplied in the form of tip pieces which are pressed on to shanks of suitable form either with brass or copper as the bracing material. It cannot be forged and can only be brought to shape by casting and grinding. In the prepared form it is said to have a hardness only slightly inferior to that of a diamond. [This might indicate that tungsten carbide enters into the composition of the material.—EDITOR.]

The prime feature claimed for the metal is that it enables the usual cuts to be taken at a greatly increased speed. It is reported that so great is the increased speed which the metal permits that no existing lathe could be found that would stand up to the work, and accordingly the Schiess-Defries Machine Tool Co. of Düsseldorf, Germany, built a special lathe in which the "Widia"-tipped tools could be used to advantage.

The lathe has 16-in. centers and can accommodate lengths up to 10 ft. It is driven by a 35-hp. continuous-current motor mounted on an extension of the bed beyond the headstock. This motor, together with change-speed gearing in the headstock, enables the main spindle to be run at speeds up to 600 r.p.m. The machine is designed to sustain cutting speeds as high as 450 ft. per min.—corresponding to work 3 in. in diameter rotating at 600 r.p.m. On work $2^1/_4$ in. in diameter a cutting speed of 330 ft. per min. has been achieved—corresponding to a rotary speed of 560 r.p.m.

The feeds are obtained from a spline shaft extending from the headstock along the full length of the front of the bed. Change gearing on the saddle gives six rates of feed, ranging from 0.1565 in. to 0.012 in. per revolution of the work; that is to say, the feed can be varied from 6 to 85 cuts per in. Quick power traverse is communicated to the saddle by means of a 3-hp. motor attached to the apron. This motor is capable of moving the saddle at a speed of 40 ft. per min., or put otherwise, of traversing the saddle the full length of the bed in about 15 sec.

Because of the high speeds and in order to reduce friction to the lowest amount, all the spindles, including the main spindle, are mounted in ball bearings. The high rotary speed was held to render undesirable the usual fixed back center. This center was consequently arranged to rotate and is mounted in ball bearings.

The machine is to be regarded as being specially designed to give economical results on long cylindrical work having small machining allowances. It is not designed as a general-purpose machine nor to take cuts of heavy cross-section. It does not, in fact, show to full advantage on heavy forgings with large machining allowances. In Germany current practice is in the direction of employing forging machines which will leave as little as possible for the machine tool to remove, and in general, of reducing machining allowances to the lowest possible amount. For that reason, it is claimed, the performance of the lathe illustrated cannot justly be deduced from the amount of metal removed per hour. There are other machines which can surpass it in this respect, but such machines, it is argued, are designed to suit the entirely different manufacturing policy of bringing the metal to shape in the machine tool rather than in the preliminary forging process. They are adapted to deal with heavy machining allowances at low speeds, and could not be profitably employed on work involving the taking of light cuts at very high speeds.

Figures for the performance of the lathe illustrated have been supplied, but they must be read in the light of the above remarks. On mild steel having a tensile strength of 38.41 tons per sq. in. the weight of metal removed was 550 lb. per hr., the depth of cut being 0.351 in. and the feed being 0.0787 in. per revolution of the work. The cross-sectional area of the cut was 0.0248 sq. in. The horsepower absorbed was 35. On steel of 50 tons to 63 tons strength the same performance was registered.

These figures may perhaps be compared with some representing the performance of "Stellite" cutting tools. Stellite is a cobalt-chromium-tungsten alloy with a small percentage of silicon and iron. From some tests carried out with the material during the war at the National Physical Laboratory, it appears that on a mild-steel bar with a depth of cut of 0.125 in. and a feed of 0.008 in., i.e., 128 cuts to the inch, the maximum cutting speed which could be employed without deterioration of the Stellite tool was 185 ft. per min. This result was stated to be appreciably better than that obtained under precisely the same condition from two varieties of high-speed steel. Some heavy cutting tests made at the works of C. A. Parsons & Co., Ltd., at about the same time (1918) showed that Stellite on a 30 to 35-ton mild steel was capable of removing metal at the rate of 450 lb. per hr. (*The Engineer*, vol. 145, no. 3761, Feb. 10, 1928, pp. 166 and 158, 3 figs., of which two completely occupy p. 158, *dA*)

MARINE ENGINEERING (See also Internal-Combustion Engineering: The Winton High-Speed Airless-Injection Diesel Engine)

The Tutin Balanced-Reaction Rudder

THIS rudder belongs to the class of balanced rudders, and like all of them pivots about an axis set some distance aft of the leading edge of the rudder. In the case of a ship fitted with a single right-handed screw, the propeller blades move continuously from port to starboard above the axis of the screw, and from starboard to port below the axis. The new rudder is designed to take advantage of the difference in the direction of flow imparted by the propeller to the water above and below the screw axis.

By pivoting about an outside axis the pressure of the water against the portion of the rudder in front of the pivoted axis assists the turning movement, and it is stated that in the Tutin rudder the degree of balancing attained is such that the power required to move the rudder is little more than that which has to be expended in overcoming the friction of the bearings.

The essential feature of the rudder is not, however, the fact that it is balanced but consists in the manner in which the rudder plate is made in sections which are set angularly to one another. There are three such sections. From the top of the rudder down to the top of the propeller disk the rudder plate, when the rudder is central, is, as in the normal type, coincident with the longitudinal central plane of the vessel. From the top of the propeller disk down to the level of the propeller axis the rudder plate, if the screw is right-handed, is set with its leading edge over toward port. The third portion extending from the propeller axis to the foot of the rudder is set with its leading edge over toward starboard. The trailing edge of both the inclined portions lies on the longitudinal central plane of the ship. The rudder plates of the two lower sections are slightly concave as seen from the port and starboard sides, respectively. The convex sides of the plates have their convexity considerably increased by the attachment to them of shaped timber sheathing. In cross-section each of the two lower portions follows the cross-sectional form of an airplane wing, the metal rudder plate corresponding to the underside of the wing, and the timber backing reproducing the upper surface. It will be gathered that looking down over the stern on both portions one would see the "upper surfaces" pointing toward each other and "lower surfaces" lying on the outside.

A development of the system consists of, in effect, forming fixed guide blades for the water in advance of the propeller. To this end the shell plating of the hull above the propeller axis is extended on the port side beyond the propeller post and curved teak filling is attached behind the extended portion. Below the propeller axis the shell plating is extended beyond the propeller post on the starboard side and similar curved teak filling is applied behind it. These extensions, it is claimed, curved as they are in opposite directions, guide the propeller inflow in a favorable manner and reduce or eliminate the eddy-making effect of an abrupt ending to the propeller post. (*The Engineer*, vol. 145, no. 3765, Mar. 9, 1928, pp. 273–274, *d*)

MECHANICS

The Kinematics of the Andreau Differential-Stroke Engine

IT IS STATED that the Andreau differential-stroke engine (see MECHANICAL ENGINEERING, vol. 47, no. 4, Apr., 1925, p. 292, and vol. 49, no. 2, Feb., 1927, p. 169) built by the Citroën Gear Co. gives the extraordinarily low gasoline consumption of 0.379 lb. per b.hp-hr., equivalent to an overall or brake thermal efficiency of about 36 per cent.

The present article deals with an investigation into the kinematics of the type of mechanism used in the Citroën differential-

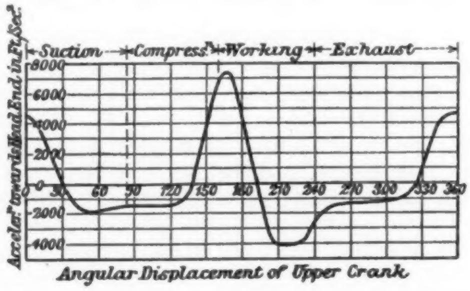

FIG. 4 PISTON-ACCELERATION CURVE OF THE ANDREAU DIFFERENTIAL-STROKE ENGINE

stroke engine and in particular examines the relative angular velocities between the big end of the connecting rod and the upper and lower links actuating the two crankshafts at given speeds. The authors also examine the curves of displacement, velocity, and acceleration of the piston and show, among other things, that the heat loss to the cylinder walls during expansion should be relatively lower than in the normal four-stroke engine. The piston speed is highest at a point in the expansion stroke reaching the very high value of 2310 ft. per min. In addition to this the obliquity of the connecting rod at this point was nearly the maximum for that side of the center line, and it is possible that the high piston speed combined with the obliquity may render piston lubrication more difficult than in a normal engine.

Fig. 4, the curve of piston acceleration, shows that the maximum acceleration also occurs during the working stroke; it reaches the extremely high value of 7300 ft. per sec. per. sec. at the beginning of that stroke, in spite of the comparatively low speed of revolution. The high inertia force required to produce this acceleration is opposed by the fluid pressure, which is also near its maximum value at this point. Thus the resulting force transmitted to the gudgeon-pin bearing is correspondingly reduced. The fact that the high value of the acceleration occurs when it does, renders it of less importance than the lesser acceleration, 4500 ft. per sec. per sec., taking place at the beginning of the suction stroke where there is no counter pressure.

From a consideration of these curves it is obvious that the motion of the piston is complex, so that equations for its motion cannot readily be found. This displacement of the piston is the resultant of the two displacements from the upper and lower links, respectively. These operate in opposite directions at certain parts of the cycle. Further, in connection with the transmission of forces from the big end of the connecting rod to the two cranks, the upper and lower links generally make a considerable angle with the direction of the force in the connecting rod. Also, in various configurations, there must be opposing forces in the respective links, so that compression in one link is combined with tension in the other in order to be in equilibrium with the force at the big end. The actual forces in the links, therefore, which act on the respective cranks will be considerably greater in magnitude than those in the connecting rod, and lead, in certain positions, to high loads on the crankpins and crankshaft bearings.

The Andreau engine is attracting very serious interest in Europe because of its low fuel consumption. (S. J. Davies and C. F. Parker in *Engineering*, vol. 125, no. 3243, Mar. 9, 1928, p. 277, 4 figs., *t*)

METALLURGY

Direct Steel-Making Process for the Manufacture of Rustless Steel

THE present article has reference to a development of the Flodin-Gustafson process (compare MECHANICAL ENGINEERING, vol. 49, no. 8, Aug., 1927, p. 917).

Briefly speaking, the process consists of the melting of briquets of iron concentrate and charcoal in an electric furnace. The percentage of charcoal is to be sufficient for reducing the iron in the ore and giving the steel the desired carbon content. The governing principle is the intimate mixing of finely distributed iron ore with charcoal, which shortens the reduction process and gives a product that can be rolled. The experiments have been going on at the Hagfors steel works of the Uddeholm Company since 1924, and the Fagerstra concern has lately acquired the license to use the method at one of its works.

The process consumes a rather large amount of electric current, but is said to yield a higher quality of steel than the older methods It has further been found that the process provides a simpler and cheaper way for making so-called rustless steel than the older methods, and attention is now chiefly devoted to the utilization of the process for this purpose. According to the report of an independent Swedish steel man, the production cost of rustless steel by this process will be rather less than 300 kroner per ton, instead of about 900 kroner per ton by the commonly used methods. (*Swedish Export*, vol. 12, no 3, March, 1928, p. 32, *d*)

POWER-PLANT ENGINEERING

Load Factor

THE author discusses the subject from the point of view of interconnection of power stations. He finds on the whole that variable load is not entirely a disadvantage, and on the contrary may turn out to be a beneficial factor from the point of view of general maintenance of the plant.

There is another aspect of the load factor which deserves consideration, namely, its influence on the fuel consumption of the station. It is often held that a high coal consumption per kilowatt-hour may be explained by a low load factor, and that a really good fuel figure can only be obtained when the load factor is high. There is a certain plausibility about that contention, because, as every one knows, generating machinery is more efficient when fully than when partially loaded. It is a false deduction, however, to conclude that a station with a high

load factor ought necessarily to be more efficient than another of equal annual output but working with a low load factor. Not only is the conclusion unsound, but experience does not show any appreciable connection between load factor and efficiency, at any rate over the range of load factors met with in central-station practice. Figures recently quoted for a turbo-generator give a steam consumption of 9.95 lb. per kw-hr. with a load of 20,000 kw., of 10.20 lb. with a load of 15,000 kw., and of 10.70 lb. with a load of 10,000 kw. Suppose such a machine to produce 30,000 kw-hr. in two hours, running with an absolutely uniform load all the time; the load factor will then be 100 per cent, and the steam consumption 10.20 lb. per kw-hr. Now, suppose the same machine to produce the same output in the same time, but by operating at 20,000 kw. for one hour, and at only half that load during the next hour. The load factor would then be reduced to 75 per cent, but the average steam consumption per kilowatt-hour would be exactly the same as before. Even had the machine run idle part of the two hours, so long as the output at the end of the time was the same, the average consumption per kilowatt-hour would remain unaltered. These figures are sufficient to show how negligible is the effect of load factor on the performance of the turbine plant in a power station. It may be argued, however, that it is in the boiler house that the effect of load factor would make itself felt, particularly on account of the influence of banking losses. But these are comparable to the no-load losses of a turbo-generator, which we have seen do not affect the question. Experience shows that if the total coal consumption of a power station over equal intervals of time is plotted against the corresponding output, the points so obtained lie along a straight line with practical accuracy. This fact is usually employed as a graphic check upon operating results, by noting the divergence of the record of any shift from the standard line. But the linear relationship of coal consumption with output involves the necessary mathematical conclusion that the coal consumption is unaffected by the load factor. The coal consumption in a light shift will be worse than on a heavy shift, exactly as the steam consumption of the turbines deteriorates as the load diminishes, but load factor, as we have shown, does not enter into the case at all. (Editorial in *The Engineer*, vol. 145, no. 3770, Apr. 13, 1928, p. 408, *gp*)

Steam Accumulators

THE author discusses the subject of increasing operating efficiency with the steam accumulator and deals primarily with the Ruths type (compare MECHANICAL ENGINEERING, vol. 44, no. 5, May, 1922, p. 323; and vol. 47, nos. 4 and 8, Apr. and Aug., 1925, pp. 295 and 619).

The purpose of the accumulator when applied to plants having fluctuating steam loads is to absorb steam at times of light load and release it instantly to meet peak-load conditions. Where process steam is used as in a sugar refinery, the accumulator supplies the process with steam at all times without reference to the source of the steam supply, making the process independent of the boiler house. At the same time it removes the fluctuating load from the boiler plant and allows it to run at a constant load, this materially increasing the efficiency of the boiler plant. It also helps to maintain the steam pressure constant, and the author gives curves showing the variations of boiler pressure in a pulp and paper mill and in a sugar refinery with and without the accumulator.

The Ruths accumulator is a cylindrical steel tank with hemispherical ends storing a large quantity of heat energy of steam and releasing this energy in the form of steam under decreasing pressure. The accumulator is set between the high-pressure and low-pressure steam line. Its presence does not eliminate the necessity for having sufficient boiler capacity to meet the average steam demand. As an example of the actual application of the accumulator the author describes an installation in a sugar refinery. Here the boiler pressure is carried at 300 lb. and the process pressures are 90 lb. for the pans and 15 lb. for evaporators, heating, etc. All electrical power is generated (Fig. 6) by two non-condensing turbines between 300 and 90 lb. as shown. The curves in Fig. 5 show the effect of the accumulator on a fluctuating steam demand. The accumulator is 16 ft. in diameter

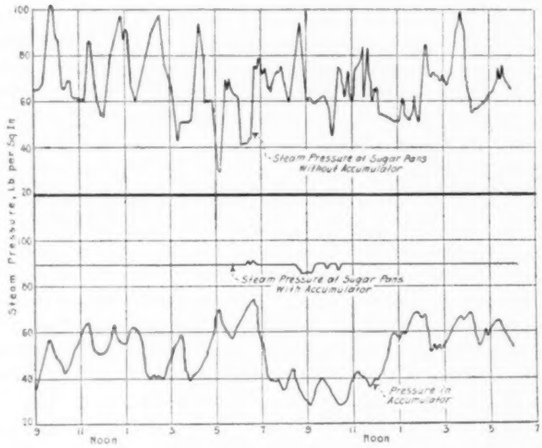

FIG. 5 STEAM PRESSURES WITH AND WITHOUT ACCUMULATOR IN A SUGAR REFINERY

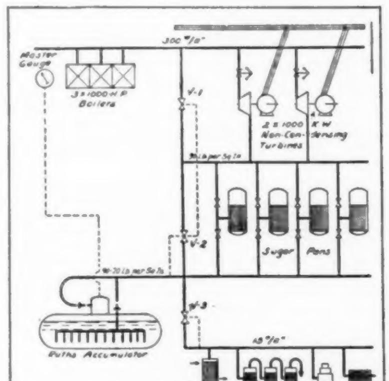

FIG. 6 TYPICAL ACCUMULATOR ARRANGEMENT IN A SUGAR REFINERY

by 55 ft. long and has a storage capacity of 45,000 lb. of steam between 90 and 15 lb. pressure.

The modern tendency in many industrial plants is to install new boiler houses for very much higher pressures than formerly, and pressures from 400 to 500 lb. are becoming increasingly common. Such installations allow of the generation of a large amount of by-product electric power between the steam pressure selected and the process pressure, which may be anything from 100 lb. down to 5 lb. Such power is obtained at a very low cost. One of the difficulties inherent in this situation, however, has been the fact that the steam demand and the electric-power demand do not coincide in their peaks, and in most cases both of them are variable. Many devices have been proposed to remedy this condition and allow of the generation of the maximum amount of by-product power without wasting any of the steam. In many cases the solution of this problem may be the installation of an accumulator which will form a flexible connecting link between all parts of the plant and serve as a balance wheel for

the steam and electric demands. In the case of the sugar refinery illustrated in Fig. 6, a larger amount of power is thus developed. (R. A. Langworthy, Vice-Pres. and Gen. Mgr., Ruths Accumulator Co., Inc., in *Combustion*, vol. 18, no. 4, Apr., 1928, pp. 244–249, 13 figs., *dp*)

Smoke Abatement in Germany and England

THE present article deals with the report of the Hamburg Association for Fire Management and Smoke Abatement for the three years 1924 to 1926, and a report dealing with the subject of smoke abatement in the cities and towns of Great Britain for the twelve months ending March, 1927. Because of lack of space these two reports are only very briefly abstracted here. Among other things the Hamburg report shows how in at least one case changes made for the purpose of eliminating excessive smoking have also materially improved the operation of the boiler. It deals also with the subject of automatic regulation of the boiler draft and fuel feed. Until recently, it is stated in the report, no automatic system of regulation of the boilers has proved entirely successful in Hamburg when tested under actual working conditions, but the engineers of the association have had under their supervision recently a small power installation provided with the Askania type of regulator, and they consider that this apparatus has filled all the demands made upon it. The Askania regulator in fact, according to their reports, provides what has so long been required, namely, a reliable and rapidly acting automatic apparatus which increases not only the draft but also the rate of firing, according to the demands of the steam-consuming portions of the plant.

The boiler to which the apparatus is attached is a Dürr vertical water-tube boiler, possessing a heating surface of 600 sq. m. and a grate area of 22 sq. m. This boiler is provided with a superheater, and with an economizer, and the fuel is burned on a mechanical traveling-grate stoker. The demands made upon the boiler vary greatly within the 24 hours, as shown by the figures given in the table below, and the difficulties that an ordinary fireman would meet with in maintaining a high efficiency under such a variable load are obvious. The Askania regulator, however, has enabled the high average efficiency of 83.5 per cent to be attained under these conditions, and the evaporation figures show that the highest efficiencies were realized during the periods of light load, when the automatic system of control would have been expected to show the worst results.

VARYING STEAM DEMANDS ON BOILER FITTED WITH THE ASKANIA REGULATOR

Time	8–12	12–16	16–20	20–24	0.4	4.8
Water evaporated, kg.	69,800	69,940	69,100	56,670	30,545	40,935
Coal consumed, kg.	7,800	8,000	6,257	5,814	3,200	4,200
Evaporation figure	8.94	8.74	9.44	9.75	9.54	9.75

The details of a test made with Westphalian nut coal are as follows:

Rate of Firing. 1470 kg. per hr. (equivalent to 66 kg. per sq. m. of grate surface per hr.)
Steam Produced. 13,624 kg. per hr. (equivalent to 22.6 kg. per sq. m. of heating surface per hr.)
Water Evaporated. 9.27 kg. per kg. of fuel (equivalent to 9.86 kg. from 0 deg. cent. and at 100 deg. cent.)
CO_2 in Waste Gases. (Average) 11.1 per cent (equivalent to an air excess of 69 per cent).

Heat Balance

	Per cent	
Steam produced	71.1	
Superheating	6.89	
Preheating water	5.51	83.5
Loss by sensible heat in the waste gases	7.4	
Unconsumed gas	0.7	
Loss by coke in the ashes and cinders	1.9	
Losses by radiation and convection	6.5	16.5
		100.0

Among other things is cited a report made by Dr. Aufhauser on tests made on the combustibility of various kinds of coals. It was found that combustibility diminishes with the age of the fuel.

The British report shows that the health officers are not very active in the majority of places in the matter of smoke abatement notwithstanding the apparent connection between pulmonary diseases and the presence of smoke. In London in 1926–1927 the amount of soot and dust actually increased, and the same, though to a smaller extent, applies to Glasgow. The town of Burnley heads the list of unabated smoke, with a total soot and dust fall equivalent to 866 tons per square mile per annum. Tables are given showing the soot and dust fall of English and Scotch towns and cities for three separate years, 1924–1925, 1925–1926 and 1926–1927. (John B. C. Kershaw in *Combustion*, vol. 18, no. 4, Apr., 1928, pp. 253–257, *gpA*)

RAILROAD ENGINEERING

The A.E.G. Powdered-Coal Locomotive

A LOCOMOTIVE of this type built by the German General Electric Co. (A.E.G.) has recently been tested on the German State Railways. After a few runs without load the locomotive was placed in irregular service on the Pankow-Strelitz line, and there made about thirty runs hauling a freight train and a locomotive. This locomotive was running idle and was intended to be used should the powdered-coal locomotive under test fail. No such occasion arose, however. The stretch on which the tests were made is fairly level and has only a few easy grades. The load, including the locomotive, amounted to about 1450 tons. Both regular soft coal and lignite (brown coal) were used. The soft coal proved to be harder to burn, nevertheless speeds up to 50 km. per hr. (31 miles) were obtained without developing smoke. Full valve-chest pressure had to be used, of course. The live-steam temperature was 400 deg. cent. (752 deg. fahr.). Smoke at the stack appeared only when still greater steam output was attempted, but there were no slag deposits on the tubes, and apparently because of vibration in running under actual operation the slag particles fall off easier than they do on the test stand, where slag formation gave trouble.

It is stated that neither with lignite nor with soft coal has there been any trouble through bridging in the tender either in the summer or in the winter. The great length of the main conveyor worm, which from a design point of view is not a desirable feature, seems, however, to have the effect of uniformly pushing forward the pulverized coal, and apparently whatever tendency to bridge over there may be, it is eliminated by the natural vibration of the locomotive while running. Air nozzles have been provided to combat bridging, but did not have to be used.

In the ashbox only very little material was found. At somewhat heavier loads the ash in the form of small granules is carried through the boiler tubes into the smokestack. After a long ride not more than 10 per cent of the ashes contained in the coal were found, while the other 90 per cent had apparently escaped through the smokestack. This makes it possible to have with powdered coal very long runs without cleaning the fires. For experimental purposes frequent changes were made from lignite to soft coal and vice versa, as a result of which alternate layers of the two kinds of coal appeared in the tender and switches from one fuel to the other were made during runs. This was done without the slightest difficulty. It is stated that the locomotive engineers were very much impressed with the ease with which all steam demands could be satisfied on this locomotive.

The remainder of the article discusses the operation of the locomotive and mentions the advantages of this system of firing. Because of lack of space this part will have to be very materially condensed.

To start up the boiler from cold, auxiliary steam of 5 to 6 atmos.

gage must be used. This steam may be obtained from another locomotive or from a stationary plant, and is introduced through the steam-heating piping. This steam is needed to operate the blower, the steam engine, and the turbo blower. The method of starting is somewhat complicated. After the steam engine has been set to start, a small fire is started in the ashbox by igniting an oil-soaked piece of waste. Hereupon the auxiliary burner is set into action. As soon as a clear flame appears the turbo blower is started and one of the main conveyor worms is set into action. The amount of fuel blown in is regulated exclusively by the blower draft, which must be strong enough to carry off the gases of combustion. In 12 min. the boiler pressure begins to rise, and in 24 min. the auxiliary steam can be shut off.

All the auxiliaries can now be supplied with steam from the locomotive boiler itself. In 30 min. a boiler pressure of 5.5 atmos. gage is obtained, which permits leaving the roundhouse. In ten more minutes the boiler pressure rises to 10 atmos. gage and in three more minutes, or 43 min. from the start, the full boiler pressure of 14 atmos. gage is obtained. The original article gives curves showing graphically the above-described process.

If the locomotive is not ready to start, the large conveyor worm and the turbo blower are cut out and only a small conveyor worm and the auxiliary blower are used. The draft fan is not used during this period.

Detailed discussion of the operation is given. One rule which is emphasized is that except at peak loads there should be no black smoke at the smokestack and only the ashes may be visible.

The author gives a calculation of the advantages in the way of fuel consumption of the powdered-coal locomotive, and among other things mentions that the standard G-8-2 German locomotive can be rebuilt to powdered coal for about Mks. 36,000 (say, $9000). In addition to this there will have to be provided six coaling stations for each 100 locomotives. The economy of operation of powdered-fuel locomotives depends, however, on local conditions, and particularly on the availability of coals suitable for pulverizing. (*Glasers Annalen*, vol. 102, nos. 4 and 5, 10 figs., *deA*)

Diesel Engines for Railway Traction

THE author discusses various types of engines and different types of transmissions, and points out the difficulties and problems in the design of Diesel-engine-driven locomotives. He comes to the conclusion that while the investment cost of the Diesel locomotive is high, the operating costs are low compared with steam practice. From this it necessarily follows that the harder the Diesel is worked the better its costs compare with steam, particularly if it can be worked long hours. Hence for a light schedule, steam is inherently cheaper, while as the daily work is made harder, the Diesel costs become less than those of its predecessor. Just where this point comes of course will be determined largely by the basic factors applying in each case, but it appears that it may be safely assumed to lie in the neighborhood of 150 miles per day for light branch-line operation on New England roads.

In conclusion, the survey of the Diesel-locomotive question shows that within the last two or three years the matter of design has progressed rapidly. Small units are out of the experimental stage and larger ones about to be tested will provide invaluable engineering experience and data. Limits which heretofore prevented the construction of Diesel locomotives of large power are being surmounted, and the originally prohibitive weight per horsepower is being rapidly reduced. Reliability and fuel and maintenance economy have been fully demonstrated. The investment charges are bound to remain high, but the possession of obsolete steam equipment is not a bar to the purchase of Diesel equipment for those applications to which the latter is suited. The apparently most promising applications are for switching in city yards, operation of industrial tracks, suburban service where the traffic density is not sufficient to warrant electrification, certain types of branch-line operation, and, particularly where fuel is expensive, long main-line hauling. (Paper presented Feb. 14, 1928, at Boston, Mass., before the New England Railroad Club. Abstracted through *Railway Age*, vol. 84, no. 11, Mar. 17, 1928, p. 635 and discussion pp. 636–638, *d*)

SPECIAL PROCESSES

Repairing by Electrodeposition

A PROCESS of repairing by the deposition of iron was described in Mechanical Engineering, vol. 44, no. 9, Sept., 1922, p. 602. In the present article another method is described in which various metals can be used, but nickel appears to be the chief agent. This process is used by Fescol, Ltd., of 101 Grosvenor Rd., London, S.W.1. Besides nickel, chromium, copper, cadmium, and other metals can be deposited, the best success, however, having been achieved with nickel and copper. The deposit can vary from 0.001 in. to as much as $^1/_2$ in., but the thickest deposit economically made is 0.080 in. The average rate of deposition is 0.020 in. thickness in 24 hr. The main principles of deposition in this process are those in common use, but in the final stage a secret solution is employed.

Parts were tested at the National Physical Laboratory. In a Brinell hardness test with steel 2 in. × 2 in. × $^1/_2$ in., coated with approximately 0.04 in. of nickel by the Fescol process, three ball impressions were made with a ball of 5 mm. diameter and a load of 750 kg. The diameters of the impressions were obtained in two directions at right angles by a measuring microscope, and the hardness numbers calculated from the formula:

$$\text{Hardness number} = \frac{\text{Load in kilograms} - 750}{\text{Spherical area of impression}}$$

The results were that with mean diameters of impression of 1.57 mm., 1.595 mm., and 1.63 mm. the hardness numbers were 377, 366, and 348, respectively. Small cracks were noticed in the nickel coating around each of the ball impressions. The hardness number of the steel on which the nickel was coated was 298.

In the adhesion test a piece of nickel coating on steel was machined with 40 threads to the inch. No breaking down of the adhesion was found under a load of ten tons, applied through the testing-machine holder screwed to the threads. On an adhesion area of 0.675 sq. in. the breaking load was 11.95 tons, or 17.6 tons per sq. in. of adhesion surface.

Among other things it is stated that worn armature shafts can be rebuilt by this method without affecting the windings. (*Electricity*, vol. 42, no. 1948, Mar. 8, 1928, p. 15, 4 figs., *d*)

Backed-Up Mills for Continuous Rolling

THIS paper describes four-high and cluster mills. The diameter of rolls has increased as the width of strip has increased. For cold rolling strip 20 in. wide, cold rolls were formerly approximately 20 in. diameter. As the rolls became larger, the arc of contact between the rolls and the strip increased approximately accordingly to the formula $b = \sqrt{Rd}$, where b = width of contact, R = roll radius, and d = total reduction.

Now the crushing strength of cold steel of low carbon varies from 70,000 to 100,000 lb. per sq. in. With each succeeding pass the crushing strength increases and may approach 250,000 lb., according to the total reduction. The total reduction in the cold rolling of low-carbon steel will range from 40 to 70 per cent of the original thickness, usually in about three or four

passes. On this basis, assuming a reduction of 20 per cent in one pass and the crushing strength of steel at 120,000 lb., we have a total pressure between rolls which (assuming that the rolls do not deform) equals:

Roll diameter, in.	Strip width, in.	Strip thickness, in.	Pressure, lb.
10	10	0.100	380,000
20	20	0.100	1,080,000
30	36	0.100	2,375,000
42	50	0.100	3,900,000

These figures are approximate, but it will be noted that in increasing the width five times, or to 50 in., the total pressure between the rolls increases approximately ten times. In other words, the pressure per inch of width increases from 38,000 to 78,000 lb. for the same percentage of reduction.

As it was impossible to design a mill with rolls of a sufficiently large diameter to take care of these pressures, backed-up mills were introduced. These mills may be of two main types: the four-roll mill, with one supporting roll for each working roll, and the cluster type, with two supporting rolls for each working roll.

The successful operation of the backed-up mill, according to the author, does not depend on roller bearings. Wide sheets and strips have been and are being both hot rolled and cold rolled on mills with ordinary bronze or babbitt bearings. In conclusion, the author states his belief that while backed-up mills are playing an important part in the rolling industry, they will not displace the two-high type entirely. The logical field is the wide-strip sheet and plate industry, and in this field they will accomplish much. There are a few other places where they can be used to advantage, and their use will gradually spread. (Lloyd Jones, Manager, Salem Division, E. W. Bliss Co., Salem, Ohio, in *Mining and Metallurgy*, vol. 9, March, 1928, pp. 133–135, illustrated, *d*)

STEAM ENGINEERING

Specific Speed and Specific Output of Prime-Mover Turbines

IN A RECENT paper (*Comptes Rendus des Seances de l'Academie des Sciences*, vol. 186, 1928, p. 124) Ch. Colombi applies to steam turbines the idea of specific speed n previously applied for a number of years to hydraulic turbines.

Colombi uses the formula

$$n_s = \sqrt{v}\,\frac{n}{E}\sqrt{\frac{P}{\sqrt{E}}} \qquad [1]$$

where v is the specific volume of steam at the exit from the elementary turbine in cubic meters per kilogram, n the r.p.m., P the output in hp., and E the energy made available by the loss of pressure in the elementary turbine in calories per kilogram. Camerer in 1899 devised the following well-known formula for hydraulic turbines:

$$n_s = \frac{n}{H}\sqrt{\frac{P}{\sqrt{H}}} \qquad [2]$$

where H is the head in meters. While both expressions are essentially of the same form, the first one does not include the second one as a particular case, because of the selection of different units. It is easy, however, to take care of this difficulty. The author himself published in 1898 the following expression for what he called the coefficient of output:

$$c = \frac{\omega^2 P}{H^{2.5}} \qquad [3]$$

which is only Camerer's expression raised to the second power, as will appear if we replace the angular velocity ω by the number of revolutions per minute n to which it is proportional.

$$c' = \frac{n^2 P}{H^{2.5}} = n^2_s \qquad [4]$$

The author claims that his coefficient (Formula [3]) is both more expressive and more convenient to use than the specific speed. Furthermore, the root may be eliminated by substituting for H the velocity $V = \sqrt{(2gH)}$. This gives the following expression for the specific output p_s:

$$p_s = \frac{n^2}{V^5}P = \frac{n^2_s}{(2g)^{2.5}} = \frac{n^2_s}{1705} \qquad [5]$$

In hydraulic turbines with a single wheel and total injection, n_s may vary from 50 to 600; p_s may therefore vary for the same kind of units from 1.5 to more than 200, and even more if a lower efficiency is permitted. If now in such a machine water is replaced by a fluid of a different density, it will be found that since the output developed is proportional to this density it will be necessary to devise an expression for the specific output in terms of density, or what amounts to the same thing, to multiply the previous expression by the specific volume v of the fluid.

$$p_s = v\frac{n^2}{V^5}P \qquad [6]$$

In this general form the expression is immediately applicable to steam or gas turbines. V is the theoretical velocity in meters per second which the fluid may have between the entrance and exit pressures of the turbine, while v is the specific volume of this fluid at the exit from the rotor measured in cubic decimeters per kilogram so as to make the units correspond to each other instead of in cubic meters per kilogram as in Colombi's formula. The author claims, therefore, that Formula [6] and not the specific speed should be used as a coefficient for the comparison of turbines. The expression [6] is, however, equivalent to that of Colombi's, as it is proportional to the square thereof.

The following example is given of the application of this formula. The last wheel of a multi-stage turbine of 60,000 hp. output with 14 wheels in series and revolving at 1500 r.p.m. gives an output of P = 4200 hp. with an exit steam pressure of 0.0372 kg. per sq. m. The volume v corresponding thereto is 38,500, and the theoretical velocity of flow of steam at the exit is V = 483 m. per sec. Substituting these values in Equation [6], p_s = 13.8.

The preceding wheel of the same turbine, the thirteenth, gives a somewhat higher p_s, namely, 16.8, which is about the limit of what can be done in a steam turbine. The specific output is therefore here very much inferior to that which can be obtained in hydraulic work, which is only natural, as in steam turbines one is limited by the ability of the rotors to resist centrifugal force and the outputs that can be obtained from electric generators. [A. Rateau (Hon. Mem. A.S.M.E.) in *Comptes Rendus des Seances de l'Academie des Sciences*, vol. 186, no. 5, Jan. 30, 1928, pp. 276–279, *tA*]

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Engineering and Industrial Standardization

250-Lb. Cast-Iron Pipe Flanges and Flanged Fittings

IN 1921 the Sectional Committee on Pipe Flanges and Fittings was organized for the standardizations of all types of flanges and fittings with The American Society of Mechanical Engineers, the Manufacturers Standardization Society of the Valve and Fittings Industry, and the Heating and Piping Contractors National Association as joint sponsors. The beginning of these standards dates back to 1894, when the A.S.M.E. after conferences with the National Association of Master Steam and Hot-Water Fitters (now known as the Heating and Piping Contractors National Association) adopted a standard flange templet for 250 lb. steam pressure which became known as the "A.S.M.E. Standard" for low pressure.

250 Lb. Cast Iron Flanged Fittings

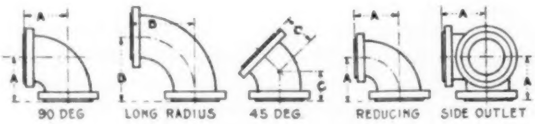

Table 4 Dimensions of Elbows

Nominal Pipe Size	Minimum Inside Diameter of Fitting	Center to Face Elbow[1,2,3,4] A	Center to Face Long Radius Elbow[1] B	Center to Face 45 deg. Elbow[1,3] C	Diameter of Flange	Thickness of Flange[1] (Min.)	Diameter of Raised Face[1]	Metal Thickness of Body (Min.)
1	1	4	5	2	4⅞	11/16	2 11/16	½
1¼	1¼	4¼	5½	2½	5¼	¾	3 1/16	½
1½	1½	4½	6	2¾	6⅛	13/16	3 9/16	½
2	2	5	6½	3	6½	⅞	4 3/16	½
2½	2½	5½	7	3½	7½	1	4 15/16	9/16
3	3	6	7¾	3½	8¼	1⅛	5 11/16	9/16
3½	3½	6½	8½	4	9	1 3/16	6 5/16	9/16
4	4	7	9	4½	10	1¼	6 15/16	⅝
5	5	8	10¼	5	11	1⅜	8 5/16	11/16
6	6	8½	11½	5½	12½	1 7/16	9 11/16	¾
8	8	10	14	6	15	1⅝	11 15/16	13/16
10	10	11½	16½	7	17½	1⅞	14 1/16	15/16
12	12	13	19	8	20½	2	16 7/16	1
14 O.D.	13¼	15	21½	8½	23	2⅛	18 15/16	1⅛
16 O.D.	15¼	16½	24	9½	25½	2¼	21 1/16	1¼
18 O.D.	17	18	26½	10	28	2⅜	23 5/16	1⅜
20 O.D.	19	19½	29	10½	30½	2½	25 9/16	1½
24 O.D.	23	22½	34	12	36	2⅝	30 5/16	1⅝
30 O.D.	29	27½	41½	15	43	3	37 3/16	2

All dimensions given in inches.

[1] NOTE: All 250 lb. cast iron standard flanges have a 1/16 inch raised face. This raised face is included in the face to face, center to face and the minimum thickness of flange dimensions.

[2] NOTE: Reducing elbows and side outlet elbows carry the same dimensions center to face as regular straight size elbows corresponding to the size of the larger opening.

[3] NOTE: Special degree elbows ranging from 1 to 45 degrees inclusive, have the same center to face dimensions given for 45 deg. elbows, and those over 45 degrees and up to 90 degrees inclusive shall have the same center to face dimensions given for 90 degree elbows. The angle designation of an elbow is its deflection from straight line flow and is the angle between the flange faces.

[4] NOTE: Side outlet elbows shall have all openings on intersecting centerlines.

This standard includes descriptive paragraphs on Sizes, Pressure, Ratings, Markings, Material, Facing, Bolting, Spot Facing, Reducing Fittings, Elbows, True Y's and Laterals, in addition to the dimensional tables which give drilling templets, center-to-face and face dimensions of ells, tees, crosses, and reducing and base fittings, including theoretical weights.

The following are the officers of the Sectional Committee and its subdivisions: Collins P. Bliss, Chairman of Sectional Committee and Sub-Committee No. 3, Steel Flanges and Flanged Fittings; Albert C. Taylor, Secretary, Sectional Committee; Arthur M. Houser, Chairman, Sub-Committee No. 1, Cast-Iron Flanges and Flanged Fittings, and Chairman, Sub-Committee No. 4, Materials and Stresses; Stanley G. Flagg, Jr., Chairman, Sub-Committee No. 2, Screwed Fittings; H. LeRoy Whitney, Secretary, Sub-Committee No. 3, Steel Flanges and Flanged Fittings; Howard A. Hoffer, Chairman, Sub-Group, Cast-Iron Flanges Under 100 Lb. W.S.P.; Ralph J. Hilliker, Chairman, Sub-Group, Ammonia Fittings; John C. Meloon, Chairman, Working Committee, Screwed Fittings; C. W. E. Clarke, Chairman, Working Committee, Steel Flanges and Flanged Fittings; Sabin Crocker, Chairman, Sub-Group, 1350 Lb. Steam Pressure; J. Roy Tanner, Chairman, Sub-Group, Loose Flanges; F. Hugh Morehead, Temporary Chairman, Sub-Committee No. 5, Face-to-Face Dimensions of Cast-Iron Flanged Valves.

A typical page of this standards pamphlet is reproduced herewith.

William J. Serrill Elected Chairman of A.E.S.C.

THE election of William J. Serrill, Assistant to General Manager of the United Gas Improvement Company of Philadelphia, to the chairmanship of the American Engineering Standards Committee is announced by the Committee. Mr. Serrill succeeds C. E. Skinner, assistant director of engineering of the Westinghouse Electric and Manufacturing Company, who has been chairman of the Standards Committee for the past three years, during which the national standardization activities of the Committee have doubled in volume.

Mr. Serrill has been prominent in standardization activities in the gas industry, and as representative of the American Gas Association he has been identified with the national standardization movement for several years. The vice-chairman during the coming year will be Cloyd M. Chapman, engineering specialist of New York City and representative of The American Society of Mechanical Engineers.

NEW AMERICAN STANDARDS

The following standards were approved by the A.E.S.C. during the month of April 15–May 15, 1928:

Industrial (Electrical) Control Apparatus. (American Standard.)

Sponsored by the American Institute of Electrical Engineers and the National Electrical Manufacturers Association. Published by the A.I.E.E.

Dimensional Standard for Cutting, Splicing, and Perforating Motion-Picture Film, and for the Apertures, Projecting Lens Diameters, and Sprockets of Motion-Picture Projectors. (American Standard.)

Sponsored by the Society of Motion Picture Engineers. Published by the S.M.P.E.

Talking and Projection of Motion Pictures. (Recommended Practice.)

Sponsored by the Society of Motion Picture Engineers. Published by the S.M.P.E.

A.E.S.C. Changes Procedure

EXTENSIVE revision of its rules of procedure to speed industrial standardization work on a national basis, is announced by the American Engineering Standards Committee. The chief object in broadening the procedure has been to make it so flexible that it may easily fit all of the varied conditions to be met in the wide range of industrial subjects covered by the Committee's work. The revision is based upon the experience of the Standards Committee during its nine years of activity as a national standardizing body.

Three important changes are made in the procedure. Heretofore each sectional committee—essentially a joint committee composed of representatives of the various groups interested in the particular work in hand—has acted under the administrative support and direction of one or more of the interested bodies, who are termed sponsors. A sectional committee may now operate autonomously, reporting directly to the A.E.S.C.; or it may act under sponsors as before. The second change recognizes "proprietary" standards and makes possible the revision of such standards within a single organization on condition that it be shown that a standard is acceptable to the groups concerned. This method is particularly applicable to highly specialized fields in which the standard of an organization has already achieved a position of recognized eminence. The third change provides for very simple cases. The approval of standards under such cases is based upon the action of a conference followed by written acceptances of the interested groups.

The revised procedure states that the different methods are founded on the principle that the basic test to be applied in all cases is the fact of the assent, affirmatively expressed, of the groups having substantial interest in the standard. Such groups have an inherent right to representation on the body dealing with the subject-matter of the standard, but it is not essential that this right be exercised.

The governing authority of the American Engineering Standards Committee is at present vested in 63 men representing 36 national organizations, industrial, technical, and governmental. About 350 national organizations are officially cooperating in the work, with 2100 individuals engaged on various committees. Up to the present time 111 national standards have been approved, and 164 additional projects representing almost all branches of industry are under way.

Minimum Standards for Electrical Products

ADOPTION of minimum standards of performance for electrical products as the next logical step in the standardization program of the electrical industry was recommended by W. S. Rugg, vice-president of the Westinghouse Electric and Manufacturing Company, who as principal speaker addressed the Second General Session of the Policies Division meeting of the National Electrical Manufacturers Association, at East Pittsburgh on March 15.

"If electrical manufacturers in the United States are to maintain their place in the world market and at the same time maintain a scale of wages which will permit our present or an advanced standard of living, this must be done through an increased attention to the costs of production and distribution. To achieve this, there must be a degree of standardization sufficient to maintain a given model until the expensive machinery necessary for its production in quantity may be justified," said Mr. Rugg.

Successful standardization already accomplished by the industry on apparatus characteristics, such as capacity, speeds, and dimensions, should be followed by establishment of quality levels of performance in Mr. Rugg's opinion.

Regarding the minimum standard of performance as a direct means of achieving economy and efficiency of production, and above all, of insuring the user of apparatus against unbalanced design and performance, and general unsatisfactory service, Mr. Rugg described the ideal minimum standard as accomplishing a balance between—

1 Lowest cost of manufacturing and distribution
2 Greatest adaptability to the purpose for which the apparatus is to be used
3 Greatest durability, or its length of life
4 Lowest cost of maintenance
5 Lowest cost of power for operating it.

Such standards should be developed to meet the interests of the major groups concerned, namely, the manufacturer, the application engineer, the manufacturer of power, and the user, and should be so adjusted as to require no immediate undue cost of redesign and retooling, and to permit a gradual raising of the standard as the producer's skill should increase.

"Minimum standards of performance should be especially advantageous in all lines of electrical apparatus which have been long enough established to have arrived at a more or less stable condition," asserted Mr. Rugg. "There could be no objection to devices having certain characteristics better than the minimum required standards. There should, however, be a penalty attached to devices in which any characteristic is below the minimum agreed standard."

"The adoption by the National Electrical Manufacturers Association of minimum standards of performance should be accomplished only after careful consultation with other branches of the industry," said Mr. Rugg. "As time goes on," he added, "we shall find that the process naturally accelerates by practice and acquaintance, and it would be but a short time when it would become more or less common practice."

"If the various members of the N.E.M.A. could come to a mutual agreement that after a certain date all bids upon the apparatus for which a minimum standard had been adopted, would contain a statement that the apparatus bid upon conformed to the N.E.M.A. standard, I believe it would effectually bring all manufacturers into line. The salesman of a manufacturer who had adopted the standard would naturally call attention to this fact and would make it a selling argument. The salesman of a manufacturer who had not adopted it would therefore continually urge upon his manufacturing plant and engineers to get in line. In other words, a manufacturer who would not conform to this minimum standard would have to make excuses."

Lowered Costs Through Standards and Mass Production

AN INTERESTING item relative to the cost of standard and non-standard goods has come to our notice recently, through the courtesy of Myron E. Steczynski, standards engineer of Fairbanks Morse & Co. The new standard for hexagonal-head cap screws, adopted by the A.E.S.C. in February, 1927, under the designation B 18b–1927, is now in extensive manufacture. The old-style screws in the 1-in. × 4-in. size are offered at $49.90 to $70.00 per hundred in small lots, while the new-style standardized screws of the same size cost but $9.00. The difference, it is stated, is due to the fact that small quantities of 100 or less do not warrant placing the job on an automatic machine. The company from which the information is received states: "We endeavor to abide by and specify our purchased and manufactured articles to recognized standards, and believe that we are reaping decided advantages from this practice."

A.S.M.E. Boiler Code Committee Work

The Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Below are given records of the interpretations of the Committee in Cases Nos. 579 and 587 to 594, inclusive, as formulated at the meeting on April 13, 1928, all having been approved by the Council. In accordance with established practice names of inquirers have been omitted.

Case No. 579

(Rescinded)

Case No. 587

Inquiry: Will it not be permissible in the markings of cast-iron low-pressure heating boilers to place the marking either on the jacket or the firing door of the new types of sheet-metal-jacketed boilers? In the new line of sheet-metal-jacketed boilers that are now on the market, it is difficult to so place the marking as to comply with the requirement in Par. H-120 of the Code that it shall be left uncovered or made readily accessible.

Reply: Par. H-120 specifically requires the marking to be stamped, cast, or otherwise irremovably attached to the front and rear cored sections of vertical sectional cast-iron boilers and on the dome section of horizontal sectional cast-iron boilers. It is the opinion of the Committee that the location of markings on the jackets or firing doors of such boilers will not be permissible for the reason that these are not essential parts of the boiler and may be displaced or interchanged.

Case No. 588

(In the hands of the Committee)

Case No. 589

Inquiry: Does the requirement in Par. P-268 of the Code for minimum number of pipe threads for connections to boilers apply to water gages and gage cocks when they are screwed directly into the shell of a vertical tubular boiler? Should water gages and gage cocks be classified as pipe connections?

Reply: It is the opinion of the Committee that water gages and gage cocks should be classified as pipe connections and comply with the requirements of Par. P-268 of the Code.

Case No. 590

Inquiry: Where the nozzle or other flanged fitting for 3-in. pipe size is required for the outlet of a boiler to operate at a working pressure in excess of 100 lb. per sq. in., is it the intent of the Code that a stop valve be connected thereto by a flanged connection, or may a companion flange be attached into which the steam line may be screwed and a valve of the screwed type used in lieu of one of the flanged type?

Reply: A screwed valve may be used provided the intervening pipe and fittings are in accordance with the Code.

Case No. 591

Inquiry: Is it the intent of Par. U-1 of the Code to exempt from compliance with the requirements of the rules of the Code for Unfired Pressure Vessels, all unfired pressure vessels coming under the limits of any one of the three limitations of this rule, or is it the intent of Par. U-1 to exempt only vessels where the diameter, cubic volume, and pressure all come under the limitations specified?

Reply: Par. U-1 stipulates that the rules of the Code for Unfired Pressure Vessels apply to vessels that exceed one or more of the limits specified therein. Therefore, it is the opinion of the Committee that if any of the limits are exceeded, the exemption of this section would not apply.

Case No. 592

Inquiry: Is it permissible, under the requirement of Par. P-248 of the Code, to form handhole openings of water-tube boilers of the water-leg type by the oxyacetylene cutting process, or is it necessary to leave a specified amount of metal to be machined off after the cutting?

Reply: Par. P-248 specifies that metal is to be left at unfinished edges of openings cut by the electric-arc or gas process only where specifically required by Pars. P-249, P-253, and P-257.

Case No. 593

Inquiry: Is it the intent of Par. P-230*b* of the Code that in applying the arch-bar type of reinforcement to crown sheets of circular form, the crown sheet may be of the shape of a semicircle, or is it essential that the part of the circle constituting the crown sheet must not exceed 120 deg. in arc, so that the edges of the crown sheet will form a corner with the side sheets?

Reply: It was not the intent of the rule in Par. P-230*b* that the crown sheet to be reinforced should be so limited in shape so as to form a corner with the side sheets. It is the opinion of the Committee that under this rule it is permissible for the crown sheet to be formed as a semicircle, but the portion that may be supported by the arch-bar form of reinforcement is limited to an arc of 120 deg. Attention is called to the fact that Par. P-230*b* specifies that the arch bars should extend over the top and down below the top row of staybolts at the sides. By top row of staybolts is meant the top row of those staybolts at the sides which run between the parallel sheets of the water legs.

Case No. 594

Inquiry: Is it necessary, under requirements of Par. U-53 of the Code as recently revised, wherein plugged threaded openings are acceptable in lieu of handholes, to provide the two plugged openings in addition to all other openings that might be specified in the head or shell of a tank?

Reply: Par. U-53 as revised provides for at least two openings for inspection purposes, which may, when the vessel does not exceed 36 in. in diameter, be in the form of threaded pipe openings. It was the intent of the Committee that these inspection openings are to be in addition to any openings used for pipe connections, but not in addition to any other openings that may be provided only for access or inspection, and they should be located in the heads or in the shell near the heads.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

ARCHIBALD BLACK, Aeronautic Division
A. L. KIMBALL, JR., Applied Mechanics Division
H. W. BROOKS, Fuels Division
R. L. DAUGHERTY, Hydraulic Division
WM. W. MACON, Iron and Steel Division
JAMES A. HALL, Machine-Shop Practice Division
CHARLES W. BEESE, Management Division
G. E. HAGEMANN, Materials Handling Division
J. L. WALSH, National Defense Division
L. H. MORRISON, Oil and Gas Power Division
W. R. ECKERT, Petroleum Division
F. M. GIBSON and W. M. KEENAN, Power Division
WINFIELD S. HUSON, Printing Industries Division
MARION B. RICHARDSON, Railroad Division
JAMES W. COX, JR., Textile Division
WM. BRAID WHITE, Wood Industries Division

Applied Mechanics

Acceleration of Water Flow Through an Orifice[1]

AM-4 If a vessel of considerable area filled with water has a very small orifice at a depth H below the surface of the water and this small orifice is opened in zero time, what time will be required for the velocity of the water issuing from the orifice to equal $\sqrt{2gH}$?

In this case we may reason as follows: Since the full height H is present at the moment of opening the orifice, the full value of V will be developed instantly. Actually, however, it will take the full time required for the static energy to change into kinetic energy, which is the time required for energy to pass over the depth H to the orifice. Since engrgy travels at the rate of 186,318 miles per second, the time element would be negligible, should the depth of the water be even as great as that of the ocean. Of course, the quantity of water visible at the other side of the orifice will be proportional to the time of flow. This answer neglects to take into consideration the viscosity of the liquid, entrance velocity, friction, etc. (Benj. G. Lowenstam, Mechanical Engineer, Edw. C. Brown and Co., Boston, Mass.)

Fuels

Waste Hemp as Fuel

F-8 With what success has waste hemp been used as fuel under steam-generating boilers? Information as to methods of preparation will prove valuable.

Experience in the burning of waste hemp has shown the following:

1 Waste hemp can be successfully used as a fuel in steam generating boilers.

2 It will deliver about 12,000 B.t.u. per pound.

3 If used alone it should be burned in a "Dutch oven"—double combustion—to prevent its passing up the stack.

4 If used under regular boilers it should be mixed with coal.

It should be understood that the term "waste hemp" as used means mill waste, which is a mixture of dust, broken short fibers, and whatever cordage oil is picked up in process. It is the result of "blowing down" and sweeping throughout the plant. (W. L. Faust, Mechanical Engineer, Whitlock Cordage Co., New York, N. Y.)

Boiler Room Labor

F-9 With 600-hp. unit-mill pulverized-coal-fired boilers, average operating conditions, reasonably automatic control, coal- and ash-handling equipment—boilers, pulverizers, and control conveniently located—how much boiler-room labor should be required for three eight-hour shifts with (*a*) three boilers, (*b*) six boilers, (*c*) nine boilers, and (*d*) twelve boilers?

In answer to this question the writer submits the following table:

Number of boilers in boiler room	3	6	9	12
Pulverizer operators	3	3	6	6
Water tender	0	3	3	6
Ash men	1	2	3	3

(H. W. Brooks, 37 Madison Avenue, New York, N. Y.)

Iron and Steel

Seasoning Castings

IS-1 What are the latest practices of manufacturers of engine parts in the seasoning of green-cast iron pistons, cylinders, or cylinder liners for the purpose of preventing distortion after machining and placing in service?

For automobile cylinders the usual practice of the writer's company is to allow the castings to age at air temperatures for three or four months, after which time very little trouble due to warping is experienced. If it becomes necessary to use cylinders which have not been aged in this manner, the following heat treatment is employed: Heat cylinders in a furnace at a temperature of 850 deg. fahr. for a period of two hours from the time the furnace reaches the stated temperature. Cool out on dry floor. (Thos. Madin, General Supt., Rolls-Royce of America, Inc., Springfield, Mass.)

Power

Steam Temperatures

P-1 What are the highest known temperatures for superheated steam, and for what purposes used?

(*a*) The highest commercially used steam temperatures known to the writer are employed in the K.S.G. low-temperature carbonization process. It is understood that these temperatures range between 900 deg. and 1000 deg. fahr. The pressures range from 5 to 15 lb. per sq. in. gage. The highest temperature at

[1] This subject has been discussed in a previous issue.

high pressure is employed at the Langerbrugge Station of the Centrales Eléctriques des Flanders, where 850 deg. at 750 lb., per sq. in. is reported. The temperature limit for high-pressure operation in this country is set at 750 deg. fahr. (R. M. Gates, Manager Industrial Department, The Superheater Company, New York, N. Y.)

(b) To the best of the writer's knowledge, the only commercial application of superheated steam to the carbonization of coal is in the K.S.G. process, in which steam superheated to temperatures approaching 900 deg. fahr. is introduced into the inner drum of the retort. Reference to this will be found in Dr. Runge's paper[2] presented at the last Annual Meeting of the Society. In this application, the steam is heated by flue gases in a superheater composed of 144 tubes, 2 in. inside diameter and 3 ft. long. These tubes, which consist of 5 bends each, are between the inlet and outlet heater. They are of seamless steel and are calorized externally. This particular superheater has been in continuous service for two and one-half years without having caused the slightest trouble. The usual temperatures of the steam are 800 to 850 deg. fahr., and occasionally 900 deg. is reached.

So far as the distillation of coal is concerned, temperatures in excess of this figure are reached only in processes which seek to carbonize coal by the sensible heat of superheated steam. No such process has been commercialized, however, because the steam must be condensed to recover the tar, and the continuous production of the large quantity of steam required is excessively expensive. This method has been considerably studied in the laboratory, where steam heated to as much as 1800 deg. fahr. has been produced in electrically wound porcelain and alloy-steel tubes. One commercial-sized experiment carbonized 50 tons of coal per day by steam heated to 1500 deg. fahr. in the carburetor and superheated in an ordinary water-gas set, which was operated as a producer and generator. (R. P. Soule, International Coal Carbonization Co., New York, N. Y.)

Wood Industries

Manufacture of Wood Flour

WI-1 Is information available on the manufacture of "wood flour" from sawdust and shavings? Where may one inspect a plant manufacturing this product?

To the extent of the writer's knowledge, wood flour is not made from sawdust and shavings but is a by-product of sandpaper operations on woodwork. Where wood flour is saved and subsequently marketed, the sandpaper machines are usually hooked up to a separate collector. Material recovered in this way is free from sawdust and shavings. The Victor Talking Machine Company, Camden, N. J., and the Singer Mfg. Co. of South Bend, Ind., have means for collecting wood flour. (P. H. Bilhuber, Asst. Factory Manager, Steinway & Sons, Long Island City, New York.)

Questions to Which Answers Are Solicited

Disposal of Sand-Blast Sand

MH-3 What are the opinions of readers of Mechanical Engineering regarding the possibility of disposing of sand from sand-blast rooms by blowing it through pipes to a river approximately 100 ft. away. Approximately three cubic yards of sand per hour must be handled. What size of fan or fans is recommended and where should they be located—at the source, point of delivery, or both?

[2] "The K.S.G. Process of Low-Temperature Carbonization," by Walter Runge.

Treating Boiler Feedwater

P-2 From the standpoint of operation and first cost, what is the proper method for treating boiler feedwater of 12 grains hardness taken from a river which, at times, contains more or less mud in suspension? The requirements are 2000 gallons of make-up water per hour for an 800-hp. boiler. The feedwater is heated to about 180 deg. fahr.

Correspondence

Contributions to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies in Research and Standardization.

America's Industrial Future

To the Editor:

A true challenge to the professional status of the engineer has been issued by Dean Dexter Kimball in his comprehensive picture of present-day civilization as printed in the March issue of Mechanical Engineering under the title of "America's Industrial Future." The importance of the part played by engineers in this age, their contribution toward its rapid progress, should be a source of great pride. Certainly a small amount of reflection and meditation should cause the active engineer to rightfully visualize the far-reaching effects of his own efforts toward the production of national wealth.

In visualizing these effects, another picture is necessary to bring home to us our responsibilities. Consider the division of labor that has been brought about, and the social problem thereby produced. To quote Gowin in his "The Executive and His Control of Men."

> The division of labor within our huge commonwealth has in a most subtle way clipped the wings of idealism. The individual has become a cog, and an unseeing cog at that.
>
> As sad a sight as an old hand-loom worker in a factory attempting to make his clumsy machine compete with the flying shuttles about him is a workingman equipped with knowledge so meager that he can get no meaning into his life nor sequence between his acts and the far-off results...... The man in the factory...... does not know what it is all about. His mind is continually focused upon narrow segments of the social life.

And with the specialization of today this narrowing effect involves business and professional men as well. The real danger confronting these leaders is that, "unable to visualize the teeming millions with whose welfare every effort of theirs, in reality, is connected up, they too, isolated, perish for want of vision."

It is a strong challenge, indeed, to the engineer. If his high professional ideals are to live, grow, and command proper respect for past achievement and conduct, he must maintain a vision of his position and duty in society.

This comment is a feeble echo of Dean Kimball's paper, a heartfelt applaud for it, and an urge to the members, especially the brother neophytes, to realize our professional duties written in and between the lines of that paper.

A. L. Voggenthaler[1]

Cedar Rapids, Iowa

[1] Jun. A.S.M.E.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

BY-LAW: The Society shall not be responsible for statements or opinions advanced in papers or .... printed in its publications (B2, Par. 3).

The Price of Air Conquest

"THE gods never give but only sell," wrote an Egyptian more than 3000 years ago. Progress in aviation has certainly been bought by a large expenditure of human life as well as of money and effort. The last victim in the endeavor to improve the airplane is W. Leonard Bonney, a highly expert flier killed May 4 on Long Island in testing an airplane with wings imitating those of a sea gull. It is not clear, and probably never will be, just how this tragedy occurred. Knowledge of the behavior of greatly curved wings is, however, very sketchy as yet, and little information is available as to the travel of the center of pressure. Before building his plane Bonney carried out some experiments at the Massachusetts Institute of Technology. It may be significant to note in this connection that notwithstanding the enormous amount of work which has been done, and particularly the experimentation in wind tunnels, not a single essential feature of the first plane flown by the Wright Brothers has undergone any material change.

Optimism

ATTENTION has been called to the fact that students in engineering at New York University have expressed the expectation of earning $7000 per year five years after graduation. Comment has also been noted to the effect that engineers are as poorly paid a class of professional men as there exists in this country. How are we to reconcile this expectation of success with the notoriously low earnings of engineers except by discounting the hopes of disillusioned youth? Is there any basis for the optimism of these embryo engineers?

In a report issued by the Committee on Investigation of Engineering Education, S.P.E.E., which was devoted to a study of graduates in electrical engineering, a curve shows that the salaries of the upper ten per cent of these graduates five years after graduation are in excess of $4000. It will not be unlikely to find among the group of men who were the subject of this investigation at least one earning the hoped-for $7000 as a proof that these young men are not dreaming of the utterly impossible. And who at the age of graduation from college is willing to admit that he cannot do at least as well as the best? He who admits his deficiencies at this age is likely to fail of fine accomplishment by not trying. He is licked before he starts. Surely the engineering profession is to be improved by the admission to its ranks of men with this fine optimism and high ambition.

Success and Education

THE college man in industry often sees little connection between his undergraduate life and its accomplishments and his subsequent success. He has, in the past, valued extra-curriculum activities above scholastic attainment, and because of notable exceptions to the rule there has been a belief that good grades are not necessarily an indication of ultimate success. It has remained for Walter S. Gifford, president of the American Telephone and Telegraph Company, to show by a careful study of his own organization that this connection is a striking one. Writing in *Harper's Magazine* for May, 1928, on the subject "Does Business Want Scholars?" Mr. Gifford renders, by the aid of his statistics, an affirmative verdict. Basing his statement on the records of 2144 Bell system employees more than five years out of college, he finds that "in general, men in the first third of their college classes are most likely to be found in the highest third of their group in salary." He concludes by suggesting that "scholarship will become a measure of mental equipment of importance both to business and to business men."

Since the World War there has been so great a rush of men to the colleges that many restrictions upon entrances have had to be made by some of the more popular institutions. Those who "view with alarm" changes in society and its mores are protesting against this wholesale extension of education to great numbers, many of whom they suspect of being unfit for this privilege. This attitude is typical of that taken not many generations ago when common-school education was proposed as a universal heritage of the children of a democracy, and subsequently when this idea was extended to secondary, vocational, and continuation-school education.

Fear and ignorance have been the deterrents to societal evolution and civilization. We may recognize the grain of truth in the epigrammatic philosophers who assure us that "knowledge increaseth sorrow," that "a little knowledge is a dangerous thing," that "of a making of books there is no end, and much study is a weariness to the flesh," but we have only to compare the condition of humanity today with that of previous epochs of history to recognize that these statements are the cries which come from the first agonies of disillusionment and the fearful awe of truth. Whatever pathway may lead to the millennium of peace will be illuminated by the light of knowledge.

Mr. Gifford makes another significant statement. "By organization, by the power to use nature which science has provided, industry has shortened the hours and eased the burden of making a living. Men work eight hours where they used to work twelve and fourteen. Vacations are longer and more frequent. Success in life, both for the individual and for the nation, depends on the use of this leisure time just as it does in the use of business time. Perhaps a mind trained to scholarship in youth may more easily find success and happiness in that leisure than one untrained."

Hours of labor are likely to decrease as the benefits of science and engineering accrue to civilization. Leisure will be the

birthright of future generations. To what purpose? Will those who attain it know how to use it? We must look to education to enlighten the mind for its appreciation.

New Section of South Kensington Science Museum Opened

THE eastern block of the Science Museum, South Kensington, London, which was described in the February, 1926, issue of MECHANICAL ENGINEERING, was formally opened by His Majesty the King, accompanied by Her Majesty, the Queen, on Tuesday, March 20, 1928.

The National Museum of Science dates from 1856 when the various objects and collections which has been acquired by the Royal Commissioners of the Exhibition of 1851 for the purpose of illustrating the application of science and art to industry, were brought together and arranged for exhibition at South Kensington.

In 1911 the President of the Board of Education appointed a Departmental Committee to inquire into the Science Museum, its organization, its aims, and its requirements, and it is from this time that the Museum in its present form really dates.

At this time the area of the exhibition galleries was estimated at 112,000 sq. ft., including offices and workshops. The committee was of the opinion that this area should ultimately be increased to 450,000 sq. ft. In order to supply this increased accommodation it was recommended that a new four-storied building, occupying the site of the existing buildings and replacing them, should be erected.

The new Museum was to comprise an eastern block, a central block, and a western block which would provide about 500,000 sq. ft. of effective space. It is the eastern block of this group which has just been formally opened.

The Philadelphia Materials-Handling Meeting

THE First National Meeting of the A.S.M.E. Materials Handling Division, held in Philadelphia, April 23 and 24, brought a confident feeling of class consciousness to this earnest and forceful group of engineers. To an observer not especially conversant with the developments in materials handling there was much that was suggestive and significant in the papers and discussion, and in the concrete examples of the Division's particular domain in the inspection trips which had been arranged by the local committee. One left the conferences with a growing appreciation of the importance to industry and to society of the benefits which engineering skill has made possible in materials handling.

The ideal of this remarkably interesting branch of engineering seems to be taken from life itself, which knows no cessation of movement or activity. To keep moving from raw-material source to finished product requires careful planning of schedules involving many factors. This the materials-handling engineer undertakes to do, and at the same time to eliminate waste of time and human labor. The reduction of the number of pickings up and settings down and costly delays which require storage in valuable space, the elimination of excessive stocks, the performance of operations on work in motion so that the production time is set by the conveyor speed, are some of the problems to which the materials-handling engineer has furnished economically successful solutions, and these have been accompanied by a remarkable lessening of human labor and fatigue.

These same engineers have scrutinized the figure of overhead and have found it a dumping ground for costs which are more accurately chargeable to production and which they have so allocated, thus drawing attention to the savings which their efforts have created.

There is a vast difference between bricks, soda ash, typewriters, and magazines, and there is great variety in the equipment to handle them. It does not require a very active imagination to think of half a dozen ways of handling ash, say in a power plant, but to design and specify the most economical system is work for a trained specialist. It is knowing "the one best way" that distinguishes the materials-handling engineer from the dilettante and results in success rather than failure or indifferent accomplishment.

The Materials-Handling Division has had its first national meeting. Other engineers will do well to sense the significance of the work this Division represents, and plan to attend its next meeting.

Charles M. Schwab and the Bessemer Medal

THE Bessemer medal is the highest honor that can be conferred by the Iron and Steel Institute of Great Britain on any person connected with the steel industry. There are few men more closely associated with the rise and progress of the American iron and steel industry than Charles M. Schwab. At the time when he started to work for Andrew Carnegie, the American steel industry was just emerging as a national industry. Steel making was as yet at the very beginning, and it was far less advanced in America than in England where the availability of pure Swedish ores gave to the operators of the Bessemer process an advantage which American makers did not have. Labor conditions in America were not as favorable as they were in England either. In the latter country the early Bessemer-steel industry could draw on the skilled crucible-steel makers of Sheffield. America had none to draw on and had to educate its workmen while still in the learning stage itself.

Schwab under Carnegie's general managership and in association with such true leaders as Capt. Wm. Jones, was probably the most prominent member of that little group of men who in the face of industrial and financial difficulties pushed the Carnegie plants to success.

In the early eighties Alexander L. Holley, foremost among those who organized the A.S.M.E., read a paper before the British Iron and Steel Institute and told the English steel makers what was being done under Schwab's managership at the Edgar Thomson and Duquesne Works. The Britishers were amazed and would not believe that steel could be made in such quantities to exact specifications. They were still more disturbed by the fact that Holley's paper amounted practically to a declaration of independence of the United States in matters of iron and steel, until then imported from England in large quantities.

Later, Schwab was the chief agent in effecting the consolidation of the leading plants of the country into the United States Steel Corporation and thus replacing the former insensate competition by a condition of stability and ultimate prosperity for the whole industry. His next work was taking over the Bethlehem Steel Company, until then a decrepit organization leading a hand-to-mouth existence on a few uncertain Government orders for armor plate and the like. What he did with this company is not only American but world history. From a little concern of purely local and no very great importance to the position of the second largest producer in the largest steel-making country of the world, is a step which would attract attention if only by its magnitude; and it becomes all the more significant because it was effected not through financial manipulation, but by sound and steady growth, taking in new products, new plants, indeed whole new industries.

Among the many leaders of American industries and, in particular, among the many truly strong men guiding the big steel-making plants of the country, Schwab represents one of the

most typical instances of success as it is understood in America. To settle in a wilderness confident that it will not long be a wilderness, to grow up with the community, to begin as a pioneer and end as a successful man, leader of local interests, has been the story of many of those who have built up America to what it is today. The only difference between these men and Schwab is that he grew up not with a place but with one of the industries most vital to the industrial life of the country, and as America became the prime steel maker of the world it was only natural that the name of Schwab should become of the few known in every part of the world and honored wherever steel is made.

The Bessemer medal was therefore in this case the ultimate formal recognition of a Work and a Man already naturally assured of a permanent place in the history of his industry and his country.

Centralized Control for Safety

IT IS GENERALLY conceded that placing all of one's eggs in one basket is not conducive to safety. It is equally true, however, that an additional measure of safety is provided if the several baskets are kept within reasonably close proximity and under the eye of a single observer.

The engineers of the Holland Tunnels observed these principles very carefully in the design of the new control board recently installed on the top floor of the Tunnel Administration Building at the Canal Street exit of the tunnel in New York City. Incorporating the latest ideas on centralized control, the board represents a truly remarkable bit of engineering. One of the first details to strike the observer is the arrangement of the instruments. The front of the board is a duplicate of the schematic layout of the electrical wiring, the switches, meters, lights, etc. appearing in the positions shown on the drawing. Across the top and bottom of the board broad bands represent the two tubes. Each section of the tubes is represented by a corresponding panel of the board. In these sections a series of lights represent the fans, traffic signals, etc., and indicate the condition of the atmosphere of each section.

The fans and other equipment and the power sources are in multiple units, but the indicating devices and controls are so concentrated on the board that a single operator may actually operate the entire tunnel equipment from this remote point. For instance, the instant the maximum allowable carbon monoxide content is reached a gong sounds and the light identifying the sections flashes up brilliantly. The operator merely snaps a small switch, and instantly another fan goes into operation. Dimming of the indicating light to its original intensity informs the operator that conditions have reached normal, and another snap of the switch cuts the fan out.

The six main power trunks, three from each side of the river, are shown in diagram and their controls are as conveniently located as those of the air-circulating system. Failure of a single line is indicated instantly by a brilliant light, and the operator shifts from one power source to another.

If a breakdown occurs in the tunnel the traffic officer throws the "stop" switch. This is instantly indicated on the control board by a string of red lights. In cases where extremely bad conditions are indicated, such as for instance a fire, the control operator may by simply pushing a button stop all traffic back of the disturbance and clear the tunnel ahead to permit entrance of the fire apparatus.

In the same room a carbon monoxide recording indicator is provided for each of the tunnel sections, so that a complete record is available at all times. It may be well to mention here that while four parts of gas in ten thousand parts of air may be breathed in safety, these indicators are set to sound the danger signal at two parts in ten thousand.

Those who have followed the story of this wonderful feat of engineering have been amply assured of its safety. Yet, witnessing the actual (not merely signaled) control from a remote point, one cannot but receive forcibly and indelibly the impression that here is a plant as safe as it is possible to make it.

The Wrought Iron Research Association

REPRESENTATIVES of the leading manufacturers of wrought iron in various parts of the country met in Pittsburgh on April 5 and formed the Wrought Iron Research Association, the principal object of which is to gather and disseminate information about this metal. Wrought iron well made is a material of recognized standing for certain purposes. Thus the use of wrought iron for locomotive staybolts is almost universal. It is also extensively used for chains, both because of the lasting qualities of the material and its ability to weld well.

Of late the wrought-iron industry has been undergoing an interesting process of transformation in that a determined and apparently highly successful effort has been made to replace hand puddling by mechanical means. Several such processes have been put into commercial operation and are apparently producing a metal of satisfactory quality.

As long as hand labor of a skilled and exhausting character was required, the production of wrought iron under American conditions could not help being restricted. This was one of the reasons why in the early days railroads had to resort to steel rails even before they were entirely satisfactory: they could not get enough wrought-iron rails when they wanted them. Now, however, that the various new processes make it possible to produce wrought iron with substantially the same classes of labor as are used in making steel, there is no reason why more of this metal should not be manufactured, and the formation of the new research association is apparently due to the recognition of these conditions and an endeavor to open new fields for wrought iron, and to call more emphatically the attention of the public generally and the engineering profession in particular to its excellent qualities.

In this the wrought-iron manufacturers are but following the modern practice of other industrial producers. In the ferrous-metals field alone there are already in existence several associations actively engaged in pushing the interests of the groups which they represent. The American Sheet Steel Trade Extension Committee was one of the earliest representatives of a large branch of the industry in this field, and has done apparently good work. The Hot Rolled Strip Association and Cold Rolled Strip Association were formed somewhat later, largely under the influence of certain disturbing factors in the trade, and have seen wise to combine into a single organization lately. The jobbing cast-iron foundries are also apparently finding unorganized operation hard sledding under present conditions, and are considering the formation of the American Cast Iron Institute.

All of these organizations can perform valuable service both to the industries which they represent and to the general public. Under present conditions it is not only concerns in the same line of business but whole industries which compete with each other, and it becomes necessary to have the advantages of each material called to the attention of the public and the engineering profession in a clear, dignified, and truthful manner, and if the associations, such as the Wrought Iron Research Association, can do this they will be really helpful both to the producers and to those who might fail to use the product because of ignorance of these qualities. Those who want to have their material known and recognized cannot rely on its happening automatically, but must be as vocal as they can in letting those who might profit thereby know of the worth of what they are making.

Henri Le Chatelier Made Honorary Member of the A.S.M.E.

As announced in the *A.S.M.E. News* of March 7, a medal and a certificate of honorary membership in The American Society of Mechanical Engineers were presented to Prof. Henri Le Chatelier, the illustrious French scientist, at a luncheon given on February 28 by Ambassador Herrick at the American Embassy in Paris. Past-President Charles M. Schwab in conferring the honors, which were made in recognition of Professor Le Chatelier's work in introducing new methods of physico-chemical analysis which are now considered indispensable in all metal-working establishments, declared the French savant one of the greatest men of his day, ranking him with Thomas A. Edison, an earlier recipient of the honor. Marshal Foch, likewise an honorary member of the A.S.M.E., the Brazilian Ambassador, and officers of the principal scientific societies of Paris were among the guests of Ambassador Herrick on the occasion of the presentation. Professor Le Chatelier's remarks in accepting the honors follow.

Professor Le Chatelier's Remarks in Accepting Honorary Membership

I am much flattered by the high honor which The American Society of Mechanical Engineers has had the kindness to confer upon me. It is a great honor for me to have been adopted by the most important technical society in the United States. One may well be surprised to see the work of a chemist rewarded by mechanical engineers. I owe this favor to the friendly relations I have had with one of your most distinguished predecessors in the presidency of this Society, Frederick Winslow Taylor.

Rather odd circumstances first threw us together. One day I was reading an article in the *Revue de Métallurgie* on the history of the discovery of high-speed steels, written by an English engineer. The latter ascribed the origin of this invention to the negligence of a clumsy workman which Taylor was supposed to have profited by. To this analysis I added some personal remarks. Having no faith in the influence of chance in the conduct of human affairs, I declared that, in order to make sure of this accidental observation and perfect a process which should revolutionize mechanical construction, Taylor must have had a great deal of knowledge.

These words came to his attention and he thanked me for taking the English engineer's "fairy tale" with a grain of salt. He told me that his discovery had been the result of a number of years of methodical study. He was going to describe it in his discourse upon the occasion of his surrendering the presidency of The American Society of Mechanical Engineers, and he sent me a copy of this address. He added that it was his intention to accomplish a work more useful still in formulating new principles for the organization of work in shops, and he asked me if I would give his study a careful examination. I did this with great pleasure. I have an ardent interest in researches of this kind, and I immediately bestirred myself to popularize the ideas of your illustrious colleague in France by an active propaganda. This was the beginning of a warm friendship which only death brought to a close.

I was not deceived as to the importance of Taylor's ideas. After having marched at the head of civilization for some hundreds of years, Europe must now go to America for counsel. Thanks to an unparalleled prosperity, you are gradually becoming masters of all the world's market. In order to keep our place in the sun we must study your methods and try to assimilate them. Missions of engineers and of workmen are continually going to the United States to inform themselves regarding this industrial evolution, of which Taylor was the initiator.

In a recent article in the *Saturday Evening Post*, an American journalist, Garet Garrett, regarded the discoveries of these missions in a humorous vein. One sees the conveyor belt in workshop practice as the keystone of your success, another, the bonus system, a third, the institution of shop councils, etc. The author of the article very unreasonably remarked that these observations in themselves only distinguish certain effects but by no means the causes of American prosperity. He would ascribe this prosperity to the American spirit, but unfortunately he does not make clear to us in what this spirit consists, nor in what quality or degree it differs from the European mind.

I have given this problem some thought. One of the most important factors of your success is, doubtless, enthusiasm in work, but among the leaders of industry on both sides of the Atlantic, this quality appears to be about equal. If our workmen accomplish less than the American workmen, they are also paid less and their wages do not accordingly increase the cost of production. For them this only results in an inferior social situation, without its constituting a very serious obstacle to our economic development. A second essential factor in the creation of all wealth is the education, the knowledge of the engineers who direct the factories. But our schools seem to be fully equal to yours; our methods of teaching are often adopted by you. Under this head there is yet another cause for our inferiority.

In order to advance civilization, that is, to make scientific discoveries and to utilize inventions, imagination is needed. We have never been reproached with lacking it. We can cite many French discoveries and inventions: the creation of chemistry by Lavoisier, of thermodynamics by Sadi Carnot, of electrodynamics by Ampère. Likewise in the field of industry we are justified in being proud of the hydraulic-cement industry created by Vicat, of the soda industry founded by Leblanc and Schloesing, of the aluminum industry, by Henri Ste. Claire Deville, of cast steel, by Martin, etc. In these industries we have as yet no competition to fear.

If labor, knowledge, and imagination are marvelous tools in the production of all wealth, it is the more essential to know how to employ them, A chisel does not make a sculptor, nor a brush an artist. Here, unfortunately, is our weak point. We lack the practical sense, wasting our labor in unproductive ways. In this matter we have much to learn from America. The struggle against the waste of effort and material so ably waged in the United States by the eminent Secretary of Commerce, Herbert Hoover, would not succeed with us. We think that where there is order, there is no pleasure. There is too much of Bohemia and Bolshevism in our taste.

Taylor's great merit has been in his organizing labor on the basis of common sense. For that very reason he is at times reproached with having invented nothing, with being satisfied

to accept principles which have long been common knowledge. The great difference between simple declaration of some more or less banal truths and putting them into practice, is not sufficiently taken into account. Taylor demanded that before setting to work, one should study the best means to employ. This is plain, practical sense, but it requires a great effort on the part of the industrial manager, and this so upsets him that generally he prefers not to make the effort.

All profit resulting from the lowering of costs ought to be divided, Taylor maintains, between capital, labor, and the consumer. This seems perfectly logical, but each wishes to keep everything for himself, and guards his personal interests as a dog guards a bone.

Finally, Taylor enjoins upon employers and employees the policy of friendly cooperation, which is indispensable for economic success, but each is suspicious of his neighbor, and the class struggle prejudices the spirit of collaboration.

The putting into practice of these simple maxims of common sense has provoked a veritable industrial revolution, and America has been able to profit by it before us.

You are, Mr. President, one of the most authoritative representatives of the new mentality to which your country owes its present prosperity. In assuming the presidency of the American Iron and Steel Institute, which is comparable to our Comité des Forges, you have recommended to your colleagues that they deal with each other in a spirit of friendly cooperation; you have pledged them to the task of replacing competitive wars with agreements founded upon mutual respect between the personnel of one establishment and that of another.

This example set by the leaders has been understood and imitated by workers. In accomplishing friendly cooperation between employers and employees, you have attained higher wages than are paid in any other country, and lower costs, in spite of all competition. We must applaud this result and hope that we shall not have to wait too long before emulating you.

Permit me to remind you that seventeen years ago, when I wrote the preface to Taylor's principles of scientific organization of labor, I already foresaw this league between masters and workers as the essential condition of our industrial rehabilitation. I am flattered to find myself thus in agreement with the old president of the greatest technical society in the work and the new president of the greatest industrial syndicate.

When the ways of friendly collaboration shall have been established in the heart of each of the nations of our old Europe, we may hope to see them flourish elsewhere and also to influence the relations between peoples. Upon that day civilization will have achieved a new advance without precedent in the history of the world.

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Newton's "Principia"

THROUGH the generosity of Dr. Edward Dean Adams, the Engineering Societies Library has recently acquired a copy of the first edition of Newton's "Principia." The volume, a large quarto in a contemporary English calf binding, is in unusually fine condition.

First editions of this famous book are exceedingly rare. Only a small number of copies was printed and these, because of the importance of the work, were rapidly distributed. A copy could scarcely be procured in 1691, four years after publication.

The "Philosophiae Naturalis Principia Mathematica" was published in 1687, in London. The Royal Society published it, but as the Society was embarrassed financially at the time, the expense of publication was actually borne by the astronomer Edmund Halley, who had first brought it to the attention of the Society. It fell to the fate of Samuel Pepys, then president of the Royal Society, to give it the imprimatur.

The "Principia" is probably the most important book on exact science ever written, and certainly is one of the most consistently original. It formulated the fundamental laws of mechanics for the first time, and the mathematical ideas required in the arguments were invented by its author. It explained phenomena which had never been explained satisfactorily before, and initiated problems that still occupy our best minds.

The Library also has an edition of the "Principia" published at Glasgow in 1822. This is a reissue of the so-called "Jesuits' edition" and is valued for the copious commentary and notes.

Of Newton's works, only one complete edition has appeared, published in 1779–1785 in five volumes. A copy of this is in the Library also.

Recent Hydraulic Research in Germany

REVIEWED BY BLAKE R. VANLEER[1]

MITTEILUNGEN DES HYDRAULISCHEN INSTITUTS DER TECHNISCHEN HOCHSCHULE, MUNCHEN, Heft 2. By DR.-Ing. D. Thoma. R. Oldenbourg, Munich and Berlin, 1928. Paper, 8 × 11 in., 72 pp., 88 illus., 5.50 r.m.

APPROXIMATELY every two years the Hydraulic Institute of the Technical University of Munich, Germany, publishes the results of its more important researches in a volume known as "Mitteilungen" or Transactions. The first volume was published in 1926 and the second (Heft 2) this year, 1928. These

[1] John R. Freeman Scholar, A.S.M.E. 1927–28; Assistant Professor of Mechanical Engineering, University of California.

transactions are published under the name of Prof. Dr.-Ing. D. Thoma, head of the Hydraulic Institute, and he is responsible for the direction, supervision, and most of the ideas contained in the volumes, although the actual data were obtained by the engineers or doctors of engineering whose names appear at the head of each article.

Physically the Mitteilungen contains 72 pages and 88 pictures and drawings showing briefly and concisely the research work of seven different engineers. The volume is prepared to furnish accurate scientific information concerning the subject treated, and this it does in a very clear manner.

The largest and perhaps the most important piece of research work is that by Dr.-Ing. O. Kirschmer, entitled "Experiments to Determine the Coefficients of Certain Weirs with Rounded Crests." This work was first performed with models in scales of 1 : 50 and 1 : 25, upon spillway weirs which have been constructed and are in use by the Mittlere Isar A.G. (one of the largest hydroelectric developments in southern Germany). The tests upon the full-scale (1 : 1) structures are also included. The two most interesting conclusions are that (1) with the same weir crest and same head, the coefficients for the models were found to vary as much as 6 per cent due to different conditions of flow; and (2) that the models gave excellent agreement with the coefficients actually found when the full-scale structures were tested.

The second paper of the Mitteilungen is, "The Influence of Elbows Installed Ahead of Venturi Meters upon the Meter Readings," by Dr.-Ing. H. Mueller. This is a valuable piece of work to the engineering profession, because it shows these influences to be very small.

In the next contribution, on "The Influence of Small Differences in the Forms of the Throats on the Readings of Venturi Meters," Dr.-Ing. J. Spangler adds further light to the subject by showing that these influences are also very small. Graphical data and dimensions are in each case given.

Experiments for determining the loss through trash racks inclined obliquely to the stream flow are then discussed by Dr. J. Spangler. This is a continuation of work of a similar nature performed in the laboratory of the Hydraulic Institute at Munich by Dr.-Ing. O. Kirschmer and published in Part 1 of the Mitteilungen. Dr. Spangler's results show that the angle of approach of the water to the racks affects very materially the loss through them. Eleven different shapes of racks were tested at angles of 0, 30, 45, and 60 deg.

The last four papers of the Mitteilungen are very brief, but give essential and important information. "Experiments for Determining the Loss in Right-Angle Pipe Tees," by Dr.-Ing. G. Vogel, gives a considerable amount of experimental data and coefficients for determining these losses, and shows that they may be materially decreased by changing the side angle of the entering lateral pipe.

"The Possibility of Errors in Weir Measurements," by Dipl.-Ing. R. Hailer, gives additional experimental evidence to support Professor Schoder's stand [Trans. A.S.C.E., vol. liii (1927), no. 7] that a sharp-crested weir is a rather uncertain device and that its coefficients depend upon the nature of the flow in the approach or weir box. These experiments also deal with the effect of elevation of downstream water, the condition of the surface of the weir crest, the nature of the baffling, and the surface of the weir box.

"New Experiments on Pressure Loss in Pipe Bends," by Dipl.-Ing. A. Hoffmann, show on the whole much lower losses than those found by the previous experiments of Williams, Hubbell and Fenkel, Balch, Brightmore, and Schoder.

"Losses in Different Forms of Elbows," by H. Kirschbach, Studien-Professor, is the beginning of what promises to be a most elaborate collection of data on about 25 different forms and shapes of elbows.

This second volume of the Munich Mitteilungen should form a part of the library of every hydraulic engineer, first to apprize him of recent scientific information in his profession, and second to be at hand in case he is confronted with problems which require the accurate and fundamental information therein given.

Few, if any, hydraulic laboratories have produced during the last two years so much research work of such a high quality as that shown in the work here reviewed, and Professor Thoma is to be congratulated upon the splendid example he is setting for other institutions.

Principles of Engineering Thermodynamics

THERMODYNAMICS APPLIED TO ENGINEERING. By Arthur F. Macconochie. Longmans, Green & Co. Ltd., New York, 1927. 260 pp., 65 figs., 13 plates, numerous tables, $4.50.

REVIEWED BY DAVID L. FISKE[2]

THE author states in his preface that the purpose of this text is to present the principles of engineering thermodynamics in the simplest fashion, and to illuminate these conceptions by reference to the best British and American practice in the major fields of their application. The publisher tells us on the jacket that he has done a good job of it, with which statement the reviewer is in agreement. He suggests that the book deserves careful looking over as a text for college courses. If the treatment coincides in point of thoroughness with what they wish to attain, teachers will find it has the merits of logical order and rigid consistency.

One who can bridge the gap from the principles to their application and attain these two desiderata is a master of his subject, in this field. The unusual feature is that the attack is from the gas end: to wit, the introduction of the kinetic theory on the first page. The conceptions of mechanics are thus employed to offer a tangible beginning, and this "*pv*" point of view, so to speak, prevails throughout. The laws of gases are developed from this beginning, and with the First and Second Laws assumed, the Carnot cycle, the absolute scale, and the conception of entropy are tied in, together with mention of availability and reversibility. The first chapter also goes into liquids and vapors, giving the essentials, after an introduction in the terms of the kinetic theory which is descriptive only.

It is fair to judge a thermodynamics text by its first chapter. This will make or break the work, and is that part which is to be thumbed over and over again, as one goes back to set himself straight on the elements of this elusive and beautiful subject. There is something more to be considered than the first chapter, however, for the student often finds in this field that he can understand the later ones, the applications, but never gets the fundamentals or their connection with the problems and practice. The usual applications are concerned in this book (after a second chapter on fluid flow)—steam appliances, internal combustion, refrigeration, turbines. The treatment ties in very well with theory, rather briefly, and without spoiling it all by being too "practical." This is a book of principles.

Discussion of a text of this sort in review involves a consideration of its applications, and requires experience in teaching, which is quite lacking in this case. The above comments have perhaps shed some light on this, none the less, implying, as they are intended to, that this is *a* presentation. The student who follows it will certainly know something about thermodynamics. He could profitably thumb the first chapter indefinitely. Others

[2] Secretary, The American Society of Refrigerating Engineers, New York, N. Y.

probably would not. The "*pv*" point of view is good as an introduction but is cumbersome for most uses, and again it seems that the introduction of liquid and vapors on top of the kinetic theory is to a degree to beg the question—if fundamentals are to be truly gone after.

This treatment, however, is excellent within its realm, as stated; it is all a question of what you want to do in teaching. If you take the bull by the horns in going after the general equations, the idea of entropy, the fundamentals from the classical point of view, the subject is beyond simplification, and it is probably true that attempts to give it all to college juniors and seniors have frequently been the cause for giving them nothing.

The book is well supported by working examples. Steam and ammonia charts are inserted in the back cover. The notation is British in appearance, as is the format. The book was evidently printed in the London plant of the publisher, although the author is an associate-professor of mechanical engineering at the University of Virginia.

Books Received in the Library

AIRCRAFT HANDBOOK. By Fred H. and Henry F. Colvin. Third edition. McGraw-Hill Book Co., New York, 1928. Fabrikoid, 5 × 8 in., 464 pp., illus., diagrams, $4.

This handbook is intended primarily for the airplane mechanic. It contains practical information upon the operation and maintenance of the standard aircraft engines of the day, upon the rigging and assembling of aircraft, upon aircraft instruments, and upon flying regulations and airport construction.

AIRCRAFT YEAR BOOK, 1928. N. Y. Aeronautical Chamber of Commerce of America, Inc., 1928. Cloth, 6 × 9 in., 551 pp., illus., portrait, maps, $5.25.

Like the volumes for preceding years, this book affords a good summary of the epochal flights of 1927, of the development of civil and governmental aviation in the United States, and of technical and commercial developments in the industry. Foreign events are reviewed, an aeronautical chronology for the year is given, and there are numerous tabulations of information frequently needed by those engaged in this field.

AUTOMOBIL-REPARATUREN. By O. Winkler. Halle (Saale), Wilhelm Knapp, 1928. Paper, 6 × 9 in., 303 pp., illus., 9.50 r.m.

A textbook for repair men, covering all the classes of repairs which can be made in a machine shop with ordinary equipment. The book covers the ground much more thoroughly and in greater detail than the usual American book of its class.

CAR BUILDERS' CYCLOPEDIA OF AMERICAN PRACTICE. Twelfth edition, 1928. Completed and edited for American Railway Association. Mechanical Division. Simmons-Boardman Publishing Co., New York, 1928. Fabrikoid, 9 × 12 in., 1288 pp., illus., diagrams, $5.

In this edition the cyclopedia arrangement introduced in the tenth edition has been elaborated with good results. Each section now contains all the information on its subject, specifications, drawings, illustrations, and manufacturers' data, so that reference is most convenient.

The book is indispensable to any one interested in the design or construction of railroad cars of any type. It brings together the standards and practices of the American Railway Association, and illustrations and drawings of cars made by the leading railroad and car builders.

CENTURY OF INDUSTRIAL PROGRESS. Edited by Frederic William Wile. Doubleday, Doran & Co., Garden City, N. Y., for the American Institute of the City of New York, 1928. Cloth, 7 × 10 in., 381 pp., $5.

In commemoration of its centennial, the American Institute of the City of New York has issued this volume of essays upon the industrial progress of the last century. Thirty authorities contribute accounts of the evolution of our industry and commerce along various major lines, such as agriculture, lumber, shipping, mining, steel, machinery, textiles, paper, printing, petroleum, merchandising, building, and aviation. The book gives an excellent historical review of the period.

DISPOSAL OF SEWAGE. By T. H. P. Veal. D. Van Nostrand Co., New York, 1928. Cloth, 5 × 9 in., 173 pp., illus., diagrams, tables, $4.25.

Intended to give the student a clear account of the main principles of sewage disposal, unencumbered by unnecessary detail. By omitting topics covered in detail in other textbooks, such as those on hydraulics, and by skilful selection and condensation, the author has been able to produce a textbook of reasonable size without omitting any of the essentials.

DRANG UND ZWANG, vol. 2. Second edition. By Ang. and Ludwig Föppl. R. Oldenbourg, Munich and Berlin, 1928. Cloth, 7 × 10 in., 382 pp., diagrams, tables, 17.50 r.m.

"Stress and strain" is written for the engineer who is already familiar with investigations of the resistance of materials and with the simpler theory as given in the ordinary texts. It is intended as a continuation of Dr. Föppl's "Vorlesungen über technische Mechanik" and offers a deeper insight into the subject by discussion and investigation of more difficult questions and more advanced problems.

The new edition of volume two has been extensively revised, especially in the sections devoted to shells and to the torsional strength of bars.

DER EINFLUSS DER MITTLEREN HAUPTSPANNUNG AUF DAS FLIESSEN DER METALLE. By Walter Lode. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, heft 303.) Paper, 9 × 12 in., 15 pp., illus., diagrams, 2.50 r.m.

In order to calculate the safe load on structural members subjected to complicated stresses, the designer must know what, under usual conditions when stresses act in all directions, limits the beginning of any permanent change of shape.

Dr. Lode has investigated the so-called flow stresses, under which a metal of given strength undergoes permanent deformation, and compared their values at various combinations of tension in two directions at right angles to each other. He has tested the various hypotheses advanced by comparing them with the voluminous numerical data available in the literature, and by new, exact experiments. As a result, he is able to select a hypothesis that agrees to within 3 per cent with experimental determinations of the flow stresses.

The author also discusses the question of the manner in which a metal undergoes permanent extension or reduction when subjected to three stresses at right angles to each other.

EVERYBODY'S AVIATION GUIDE. By Victor W. Pagé. Norman W. Henley Publishing Co., New York, 1928. Cloth, 5 × 8 in., 247 pp., illus., diagrams, $2.

A catechism upon all phases of aviation, intended for the general public. The author succeeds in answering briefly and intelligibly most of the questions about the construction and operation of aircraft that the ordinary person asks.

ENERGIESPEICHERUNG. By W. Pauer. (Wärmelehre und Wärmewirtschaft in Einzeldarstellungen, band VI.) Theodor Steinkopff, Dresden and Leipzig, 1928. Paper, 6 × 9 in., 179 pp., diagrams, 12 r.m.

A general discussion of the methods of storing energy available for use in power plants. Flywheels and methods of storing water power, the storage of heat in liquids and solids, and steam

accumulators are all discussed, their properties set forth, and their uses pointed out. The determination of maximum demands on power plants is considered. The book is a useful review of the various methods by which energy is stored, either purposely or as a more or less accidental by-product.

FOUNDRY WORK. By R. E. Wendt. Second edition. McGraw-Hill Book Co., New York 1928. Cloth, 5 × 8 in., 236 pp., illus., diagrams, tables, $2.

A textbook intended to give engineering students the fundamental principles of foundry work and a general knowledge of foundry practice. This new edition has been reorganized and considerable new material added.

GETRIEBE [reprinted from *Maschinenbau*]. V.D.I. Verlag, Berlin, 1928. Paper, 9 × 12 in., 46 pp., illus., diagrams, 2.75 r.m.

Fourteen articles on gearing and belting which have appeared in recent issues of *Maschinenbau* are here brought together in convenient form for reference. They deal with the design and construction of straight-axis spur gears, heavy-duty gearing, locomotive and crane gears, the improvement of belt drivers, hydraulic gears, and similar topics.

HANDBOOK OF MECHANICAL REFRIGERATION. By H. J. Macintire John Wiley & Sons, New York, 1928. Fabrikoid, 6 × 9 in., 724 pp., illus., diagrams, tables, $7.50.

This book aims to include all the information upon mechanical refrigeration which the engineer is likely to need. It presents some theory as a basis for the fundamental formulas, as well as all the information required for understanding the design and operation of various systems.

Starting with the compressor, the author deals with absorption machines, fittings, condensers, automatic machines, refrigerants, brine systems, water supply, erection, operation, and testing. He then considers ice making, cold storage, air cooling and conditioning, hotel and apartment refrigeration and refrigeration in the chemical industries, safety devices, fire protection, costs, specifications. Motors and engines are also discussed.

HAUSHALT-KÄLTEMASCHINEN. By R. Plank. Julius Springer, Berlin, 1928. Paper, 6 × 9 in., 96 pp., illus., diagrams, 7.50 r.m.

During a tour of observation in America in 1927, Dr. Plank paid particular attention to household refrigeration. The results of his visit, together with those of his investigations of European apparatus, are given in this book. He points out the characteristics of compression and absorption machines, describes most of the machines on the market, and compares critically the two types.

HENRY CLAY FRICK, THE MAN. By George Harvey. Charles Scribner's Sons, New York, 1928. Cloth, 6 × 9 in., 382 pp., illus., portraits, $5.

An interesting authoritative biography. Traces his commercial activities from the formation of Frick & Co., in 1871, to his retirement from the Carnegie Steel Co. in 1900. Gives an account of the ensuing litigation, of Frick's connection with the United States Steel Corporation, and his later life and public interests.

KESSELANLAGEN FÜR GROSSKRAFTWERKE. By Friedrich Münzinger. V.D.I. Verlag, Berlin, 1928. Linen, 8 × 11 in., 176 pp., illus., diagrams, plates, 19 r.m.

In the first two-thirds of this book Dr. Münzinger gives a detailed account of the boiler plant of the Klingenberg power plant of the Berlin municipal electric system, from the original project to the completed installation. The various preliminary plans are described critically, and the various steps in building, such as the construction of the boilers and accessories, erection, etc. are narrated, with attention to points of interest. The text and the numerous illustrations give an unusual picture of the many problems involved in a large plant.

With this as an example, the author then takes up the claims made for modern methods of firing and modern high-pressure boilers, and points out the ways to be followed to fulfil them. Further possible economies are pointed out.

MODERN CALORIMETER. By Walter P. White. Chemical Catalog Co., New York, 1928. (American Chemical Society. Monograph series.) Cloth, 6 × 9 in., 194 pp., illus., diagrams, tables, $4.

The writer of this treatise is one of a small body of investigators who have of late been engaged in the study of the difficulties encountered in accurate calorimetry. He here presents a unified account of the progress that has been made in determining the conditions of precision in calorimetry and the improvements in method which have resulted from it. It will be of interest to those desirous of ascertaining the attainable precision of reliability of various methods or designs in calorimetry.

PHYSICS IN INDUSTRY: Vol. 4, Physics in the Rubber Industry, by Walter Makower, and The Physicist in Agriculture, by Bernard A. Keen. Oxford University Press, London and New York, 1926. Boards, 6 × 10 in., 63 pp., diagrams, $1.

Contains two lectures, upon Physics in the Rubber Industry with Special Reference to Tire Manufacture, and upon the Physicist in Agriculture with Special Reference to Soil Problems. These lectures which were delivered in 1925 before the Institute of Physics, point out the contributions of physics to these two great industries, and call attention to problems needing further research.

POWER'S PRACTICAL REFRIGERATION. Compiled by L. H. Morrison. McGraw-Hill Book Co., New York, 1928. Cloth, 6 × 9 in., 259 pp., illus., tables, $2.50.

A handbook of practical information upon the construction, maintenance, and operation of refrigerating machinery. The text is simply written and assumes no scientific knowledge. It is based on articles that have appeared in *Power*.

SCHALTBILDER IM WÄRMEKRAFTBETRIEB. By W. Stender. V.D.I. Verlag, Berlin, 1928. Paper, 6 × 8 in., 27 pp., illus., 1.80 r.m.

This little book presents a carefully planned set of symbols for use in representing power-plant machinery diagrammatically. Upon the basis of a few primary symbols, a complete system has been logically planned, which cares for all power-plant machinery and combinations.

STATISCHE UND DYNAMISCHE UNTERSUCHUNG VON MÜNDUNGS-DAMPFMENGENMESSERN. By S. Kreuzer. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, No. 297.) V.D.I. Verlag, Berlin, 1928. Paper, 8 × 12 in., 34 pp., diagrams, tables, 4.50 r.m.

Reports the results of an unbiased investigation of two well-known models of steam flow meters, in which the influence of their mechanical design upon their accuracy was determined and special attention was paid to their behavior when measuring rapidly alternating and pulsating currents. It was found that the usual forms of apparatus cannot measure pulsating currents satisfactorily. The investigations also clarified the influence exerted by the method used to transmit the difference in pressure to the indicating device.

On the basis of the information obtained, a new meter was built and tested which gives both the difference in pressure and also the amount of flow through the throttling device in a given time. It also proved reliable for metering pulsating currents. The investigations are fundamental in character. The results can be applied to other models than those tested.

STUDIENBERICHT ÜBER DIE ABDICHTUNG VON WASSERDURCHLÄSSIGEM FELS UND MAUERWERK IN EISENBAHNTUNNELS. By K. E. Hilgard. Julius Springer, Berlin, 1928. Paper, 6 × 9 in., 15 pp., 1.20 r.m.

A brief discussion of the problem of water in railroad tunnels. The author discusses the origin of leaks in tunnel linings, the inconveniences that result, and the methods of waterproofing that have been applied to leaking tunnels and during construction.

VI. TAGUNG DES ALLGEMEINEN VERBANDES DER DEUTSCHEN DAMPFKESSEL-ÜBERWACHUNGS-VEREINE, am 9 Sept., 1927, zu Düsseldorf. V.D.I. Verlag, Berlin, 1928. Paper, 9 × 12 in., 78 pp., illus., diagrams, tables, 16 r.m.

This report of the proceedings of the sixth annual convention of the general association of German boiler-inspection societies gives an interesting view of some of the important questions of the day concerning boiler economy, materials, and experience.

Among the topics treated are: the economic limits of steam pressure; the economy of pulverized-coal firing; boiler materials and their modification by further working and use; and experience with that Benson boiler.

THEORIE DER REDUKTIONSFÄHIGKEIT VON STEINKOHLENKOKS. By George Agde and H. Schmitt. Wilhelm Knapp, Halle (Saale) 1928. (Kohle, Koks, Teer, bd. 18.) Paper, 7 × 10 in., 165 pp., diagrams, tables, graphs, 16.50 r.m. Bound, 18.50 r.m.

Presents the results of an elaborate research upon a problem of great importance to users of coke in blast-furnace cupolas, cement furnaces, etc. The authors have investigated the various factors which might affect "reactivity," "combustibility," or "reduction capacity," as it is variously termed, and have arrived at a theory to explain the variations in the efficiency of different cokes based on their experimental results.

A TREATISE ON THE ANALYTICAL DYNAMICS OF PARTICLES AND RIGID BODIES. By E. T. Whittaker. Third edition. University Press, Cambridge; Macmillan Co., New York, 1927. Cloth, 7 × 10 in., 456 pp., $8.50.

A treatise intended mainly for the advanced mathematician. It collects into book form the outlines of a long series of researches scattered through many periodicals. Numerous examples for solution are given. The first fourteen chapters of this edition correspond closely to those in the second. The last two chapters, on the general theory of orbits and integration by series, have been completely rewritten.

UNTERSUCHUNGEN ÜBER DIE WASSERRÜCKKÜHLUNG IN KÜNSTLICH BELÜFTETEN KÜHLWERKEN. By Friedrich Wolff. R. Oldenbourg, Munich and Berlin, 1928. Paper, 8 × 11 in., 62 pp., diagrams, plates in pocket, tables, 9 r.m.

An experimental investigation of the laws governing the exchange of heat between water and air in forced-draft cooling towers. The research was carried out in the mechanical laboratory of the Charlottenburg Technical Institute.

WÄRMEDURCHGANG BEI EINFACHEN KÖRPERN UND MASCHINEN: Vorträge auf der 2d Tagung des Ausschusses für Wärmeforschung im Verein deutscher Ingenieure. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, No. 300.)

This pamphlet contains the papers presented at the second (1926) annual convention of the Committee for Heat Research of the Society of German Engineers.

Dr. H. Gröber discusses the mathematical determination of the changes of temperature in periodically heated bodies, such as furnaces, regenerators, gas-engine cylinders, etc. Dr. M. Jakob discusses the transmission of heat from condensing steam. The transmission of heat by cylinder walls is the subject of two thorough investigations by Dr. W. Nusselt and Dr. A. Nagel. Dr. G. Eichelberg presents the results of a study of the transient course of heat transmission in the Diesel motor. Dr. L. Richter takes up problems of cooling automobile and airplane engines.

WERKSTOFF- UND BAUVORSCHRIFTEN FUR LANDAMPFKESSEL NEBST ERLAUTERUNGEN. Jan., 1928. By Deutscher Dampfkesselausschuss. Beuth-Verlag, Berlin, 1928. Boards, 6 × 8 in., 86 pp.

Contains the specifications and testing methods for stationary-boiler materials and workmanship approved by the German Boiler Committee for use after January 1, 1928.

Synopses of A.S.M.E. Transactions Papers

THE papers abstracted on this and following pages appear in the current sections of A.S.M.E. Transactions as published in its new form. These sections have been sent to all who registered in the Aeronautic, Fuels and Steam Power, Iron and Steel, Materials Handling, and Wood Industries Divisions. Other sections are in the course of preparation and will be announced, when completed, in later issues of "Mechanical Engineering."

AERONAUTIC PAPERS

Progress in Aeronautics

THIS report, prepared by the A.S.M.E. Aeronautics Division, reviews the rapid growth during 1927 in the various phases of aviation activity. It gives brief particulars regarding new engines introduced during the year, and discusses developments in airplane design and construction, progress in aerodynamics, air transport and aerial service, aerial surveying, aircraft materials, airships, and the activities of the Navy and of the Aeronautics Branch of the Department of Commerce. [Paper No. AER-50-1]

Facilities for Research Work in Aeronautics in the United States

THIS paper gives particulars regarding the aeronautical laboratories at New York University, Massachusetts Institute of Technology, California Institute of Technology and Stanford University, which have been established through gifts from the Daniel Guggenheim Fund, as well as of the laboratory at the University of Michigan. Information concerning their equipment is also included, and in some cases the courses of study offered are outlined. [Paper No. AER-50-2]

Oleo Gears for Aircraft

By EDWIN E. ALDRIN

First Lieutenant, U. S. A. Air Corps, Material Division, Wright Field, Dayton, Ohio

AFTER describing the various oil damping devices for reducing the landing shocks of airplanes, the author presents a theory and test data for the design of the "oleo" type of landing gear. This type depends on the flow of oil past an orifice for the shock-absorbing effect. Tests on several forms of orifice using different fluids under a steam hammer gave satisfactory orifice coefficients for design purposes. Then landing gears were dropped under weights with different combinations of orifice and needle, wheel, and tire through heights varying up to 42 in. and their performance studied in slow-motion pictures and cards from pressure indicators attached to the gears. In the plain oleo mechanism together with tire and wheel, it has been found that almost constant deceleration is obtained with no tapering needle in the oil orifice. Viscosity of oil medium has little effect. The paper has two appendixes, one of them giving respectively maintenance instructions for Curtiss oleo struts and for Curtiss oleo wheels. [Paper No. AER-50-3]

The Development of Large Commercial Rigid Airships

By KARL ARNSTEIN

Vice-President in charge of Engineering, Goodyear Zeppelin Corporation, Akron, Ohio

IN THIS paper the author discusses the safety of the airship, which he considers to be very high because of the multiplicity and overlap of various means of achieving the same end. He then analyzes the various types of load, aerostatic and aerodynamic, which an airship experiences, and makes well-based recommendations for methods of structural analysis, and for load factors. On the basis, partly of past experience, partly of careful investigation of many projects, he studies the variation in weight with volume of various structural elements. He finds that the specific deadweight still decreases for airships up to 15,000,000 cu. ft. capacity, although only slightly beyond this point. From the point of view of transportational efficiency, the improvement with larger sizes continues almost indefinitely, at any rate well beyond the 15,000,000 cu. ft., which is the largest volume contemplated at present. On the grounds of exhaustive theoretical investigation on the one hand and extensive practical experience on the other, the author states that it is possible to construct rigid airships of any size which may be required to meet any transportation problems, and that the economy with regard to useful load, transportational efficiency, ton-mileage, and building costs becomes more favorable with increase in size. [Paper No. AER-50-4]

Metallurgy of Aircraft Engines

By BISHOP CLEMENTS

Metallurgist, Curtiss Aeroplane and Motor Corporation, Buffalo, N. Y.

THE author first enumerates the steels which have been found to be the most suitable for connecting rods, crankshafts, gears, bolts, studs, and nuts, nearly all of these being standard S.A.E. materials. He then briefly discusses brasses and bronzes, giving particular of two copper-aluminum alloys used for valve-seat inserts, and concludes with a brief consideration of weight-saving aluminum and magnesium alloys. [Paper No. AER-50-5]

A New Propeller-Type, High-Speed Windmill For Electric Generation

By E. N. FALES

Aeronautical Engineer, Dayton, Ohio

A NEW technology of windmill research adopted from aeronautics has resulted in an improved type of windmill resembling an airplane propeller which because of its high speed, light weight, low cost, and good efficiency may under certain conditions compete with internal-combustion-engined farm-lighting plants. Extensive wind-tunnel and other tests used to perfect the new windmill are described and the theories of design are explained in the first section of the paper. The second section presents a study of the velocity and prevalence of winds at Dayton, and explains how these conclusions can be adopted for other localities, using a few basic wind values for those localities. Given the power output required momentarily and on a monthly basis, and the velocity and frequency of the winds, the windmill diameter can be calculated. Empirical coefficients are presented for relating the effects of widely ranging winds with steady wind conditions used in the laboratory for determining fundamental design factors. [Paper No. AER-50-6]

Materials for Aircraft Parts Subjected to High Temperatures

By J. B. JOHNSON

Chief, Materials Branch, Engineering Division, Air Service, War Department, McCook Field, Dayton, Ohio

THE author discusses the operating conditions and materials now being used and the desirability of developing better materials to meet the requirements of modern design. After stating the temperatures which are attained in the various engine parts, he considers at some length the selection of materials for cylinder heads, pistons, valves, and valve seats. [Paper No. AER-50-7]

Development of the Buffalo Airport

By JOHN M. SATTERFIELD

Chairman, Buffalo Air Board, Buffalo, N. Y.

THE author, after giving particulars of early work done in planning the airport, the site of which comprises 518 acres, proceeds to discuss the general layout, runways and drainage, power and other lines, hangars, garage, rolling stock, administration building, etc. Plans and aerial views of the airport are included. [Paper No. AER-50-8]

FUELS AND STEAM-POWER PAPERS

Papers Presented at the First National Fuels Meeting, St. Louis, Mo., Oct. 10–13, 1927

TWENTY-FOUR papers were presented at this meeting, dealing with a wide variety of subjects and capable of being roughly classified under the headings General, Power Plant, Industrial, and Smoke Abatement. These papers, which are listed below, are published together as a group and are not available singly. In ordering ask for No. FSP-50-1/24.

Fuels, Past and Prospective, S. W. Parr.
American Fuel Resources, O. P. Hood.

Combustion and Heat Transfer, R. T. Haslam and H. C. Hottel.

The High Cost of Fuel Saving, W. Trinks.

Application of Powdered Coal to Small Boilers of Industrial Plants, Henry Kreisinger.

The Clinkering of Coal Ash as Related to Laboratory Fusibility Determinations, A. C. Fieldner, W. A. Selvig, and P. Nicholls.

Factors Governing the Purchase of Coal, M. B. Smith.

Properties of Refractories and Their Relation to Conditions in Service, S. M. Phelps.

Characteristics of Modern Boilers, E. R. Fish.

Direct-Fired Powdered-Fuel Boilers with Well-Type Furnaces at Charles R. Huntley Station, H. M. Cushing and R. P. Moore.

The Use of Fuels in Brick Kilns, W. E. Rice.

Progress in Gas-Producer Practice, W. B. Chapman.

The Burning of Liquid Fuels, E. H. Peabody.

Automatic Combustion Control, T. A. Peebles.

Characteristics of Modern Stokers, F. H. Daniels.

The Economics of Air Preheater Application, F. M. Van Deventer.

Economics of Dry-Quenching Coke by the Sulzer Process, A. N. Beebee.

The Preparation of Coal with Special Reference to Quality, William Beury.

Railway Smoke Abatement, J. B. Irwin.

The Measurement of Atmospheric Pollution, Visible and Invisible, G. T. Moore.

Smoke-Abatement Methods Used in Cleveland, E. H. Whitlock

Organizing a Smoke-Abatement Campaign, Erle Ormsby.

Smokeless and Efficient Firing of Domestic Furnaces, V. J. Azbe.

The Effect of Atmospheric Smoke Pollution, A. S. Langsdorf.

IRON AND STEEL PAPERS

Progress in the Iron and Steel Industry

THIS report of the A.S.M.E. Iron and Steel Division briefly surveys the most important developments of the year, among these being the manufacture of large seamless tubing, continuous steel-sheet rolling, electric mill drive, new rolling-mill records, the application of hot blast to foundry cupolas, development of permanent-mold casting, etc. [Paper No. IS-50-1]

Developments in 4-High Rolling Mills

By F. C. BIGGERT, JR.

President, United Engineering and Foundry Co., Pittsburgh, Pa.

UNTIL about a year ago existing mills were unable to hot-roll strip in widths exceeding 24 in. However, the 206-in. 4-high plate mill at the Lukens Steel Co. demonstrated that plates as thin as $^3/_8$ in. could be rolled in widths up to 16 ft. and with a uniformity of gage from edge to center as good as previously obtained in the narrow widths. The author in the course of his treatment of the subject, discusses difficulties encountered in rolling wide and thin material, early 4-high mills, hot and cold rolling, mill capacities, power consumption in rolling, tin-plate-mill requirements, use of roller bearings, and the size, motion, and composition of rolls. [Paper No. IS-50-2]

Destruction Test of a 66-In. Forged Steel Penstock Pipe

By JOHN L. COX

The Midvale Company, Philadelphia, Pa.

THE section of pipe tested is representative of a portion of one section of the penstock of the Big Creek Power Plant No. 2, near Los Angeles, Calif., of the Southern California Edison Co., with the object of determining the elastic limit and ultimate strength as well as the deformation and behavior under high pressure.

Details and specifications of the pipe section are given as well as a description of the test arrangements and measuring apparatus. The test is described and the results are given in tabular and graphic form.

The pipe reached its elastic limit at a pressure of 2150 lb., corresponding to a tangential stress of 25,000 lb. per sq. in. in the steel of the walls, the measured proportional limit of the steel at the ends being 24,500 lb. The pipe failed at a pressure of 5300 lb., which, by the approximation of the extended Birnie formula, would correspond to a fiber stress of 62,000 lb. per sq. in., compared with an actual tensile strength of 67,750 lb. The external expansion was 6 in. in diameter or 8.3 per cent. The internal expansion was $6^3/_8$ in. in diameter or 9.63 per cent. The mean expansion of the wall was 8.96 per cent. The reduction in wall thickness at the mid-length of the pipe at the fracture was $^3/_{16}$ in. or 6.25 per cent. The paper closes with a discussion of the results of the test. [Paper No. IS-50-3]

MATERIALS-HANDLING PAPERS

Progress in Materials Handling

THIS report of the A.S.M.E. Materials Handling Division summarizes the rapid progress made during 1927 in the development of materials-handling equipment and in the application of that equipment to the needs of individual plants, mines, construction, railroads, and marine carriers. In its preparation questionnaires were circulated among several leading manufacturers and users of equipment, resulting in the procurement of a large body of helpful information. Development specifically discussed are those in cranes, hoist and tramrail equipment, elevators, electric and lift trucks, skid shipment of materials, gasoline trucks and tractors, conveyors, etc. A bibliography of some 400 articles on materials handling recently published in technical periodicals is appended to the report. [Paper No. MH-50-1]

Sugar-Warehouse Conveying Systems

By JOSEPH T. BUZZO

Mechanical Engineer, Construction Department, California and Hawaiian Sugar Refining Corp., San Francisco, Calif.

IN THIS paper the author describes conveying equipment installed at the Crockett, Calif., plant of the California and Hawaiian Sugar Refining Corp. First a general description of the plant layout is given, together with an explanation of certain conditions which demand large storage facilities for both raw and refined sugar. Among the types of conveyors described are belt conveyors, depressed floor conveyors, slat conveyors, a specially designed screw conveyor, and various portable and semi-portable conveyors. The duty to be performed by each of these types is mentioned, and the maintenance problem is

discussed. An interesting weighing conveyor, which receives the bagged sugar directly from the steamer, is described. A part of the paper deals in an explanatory manner with the very interesting central-control board, through which the entire system is under instant control. An interesting comparison of manual and conveyor handling is given, with the figures well in favor of the latter method. [Paper No. MH-50-2]

Operating Costs of Electric Industrial Trucks And Tractors

By C. B. CROCKETT AND H. J. PAYNE

The Society for Electrical Development, Inc., New York, N. Y.

THE authors attempt to show how direct and indirect costs of a materials-handling system may be classified and estimated, and apply the methods described to the question of operation of electric trucks. The direct costs of operation are here divided into fixed charges and operating charges, both of which are enumerated and, where possible, estimated. Factors affecting the costs are likewise enumerated and actual figures of cost of operation taken from several plants are presented, and the savings due to truck operation are pointed out. [Paper No. MH-50-3]

Materials Handling as an Aid to Production

By FRANK L. EIDMANN

School of Engineering, Princeton University, Princeton, N. J.

THE author surveys the materials-handling problem of a plant from eight angles: the design of building and arrangement of equipment, the weight of material handled per pound of finished product, the elimination of hand labor, the effect of the materials-handling methods on inventory, the effect on increased output of the worker, the design of the product to facilitate handling, the selection of the handling equipment, and attempts to facilitate handling in shipment and in customer's plant. Examples of good and bad practice are quoted, and illustrations of some are included. [Paper No. MH-50-4]

Cargo Cranes—Types Available, Factors Governing Selection, and Latest Developments

By BERNARD DUNELL

Local Manager, C. C. Moore & Co., Engineers, Vancouver, B. C.

IN THIS paper the author discusses the several types of cranes used on docks for removing cargoes from ships and placing the articles handled, that is, crates, barrels, bundles, etc., at the points desired. Two general types of cargoes must be handled: namely, bulk cargo and general cargo. The disadvantages of some of the common types are mentioned, and the manner in which these have been eliminated in later designs are pointed out. The types of loads best handled by different types of equipment are mentioned, and recommendations as to proper equipment are made. It is shown that, while in some cases as high as 50 tons must be lifted, the most popular general-cargo crane is of from three to five tons capacity. The author emphasizes the importance of proper attention to dock conditions in the determination of wheel loads, and therefore the crane capacity in the case of existing docks, and where new construction is contemplated the desirability of adequate strength to take care of the maximum load likely to be imposed. The hoisting rope receives considerable attention in the paper. The disadvantages of the two-strand fall are pointed out, and it is recommended that it be avoided wherever possible. A disadvantage of the ordinary luffing crane is that when the jib is luffed in the load suspended from the jib head is simultaneously raised, resulting in wasted work and requiring a more powerful motor than otherwise would be necessary. Level-luffing cranes are described which overcome this objectionable feature and permit more flexible operation. The various arrangements of compensators and counterweights to permit this are described. [Paper No. MH-50-5]

WOOD-INDUSTRIES PAPERS

Progress in the Woodworking Industries

THIS report, contributed by the A.S.M.E. Wood Industries Division and first published in the January, 1928, issue of Mechanical Engineering, deals briefly with timber conservation, research, both proposed and under way, the trend of woodworking-machinery design toward inbuilt electric motorization, high-speed-steel cutting tools, standardization in lumber grading, and the increasing use of nitrocellulose lacquer finishers for wood surfaces. [Paper No. WDI-50-1]

Increasing the Production of Woodworking Machines by Use of Direct-Connected Alternating-Current Motors

By W. A. FURST

Manager, Engineering Division, Westinghouse Electric & Manufacturing Company, Detroit, Mich.

THE author, after recounting the drawbacks of belt drive, points out the advantages gained by using direct-connected built-in individual motors on each cutter head and on the feed, some of them being: the possibility of using a cutter head with fewer knives and of running the motor at a higher speed than attainable with a belt drive; individual operation of heads; automatic stopping of machine when work becomes jammed in the machine, etc. He then devotes the major portion of the paper to information of interest to those desiring to increase the production of their machines, dealing with choice of motors, speeds, methods of obtaining high frequency, etc., showing how with a combination of the induction frequency generator and the various pole combinations on the motor a range of speeds suited to any particular type of machine may be obtained. [Paper No. WDI-50-2]

The Pulp and Paper Industry and the Northwest

By C. C. HOCKLEY

Consulting Engineer, Portland, Oregon

THE purpose of this paper is not to disclose the details of any one process, but rather to furnish a glimpse of the industry as a whole, and in particular that part of the industry using wood fiber, and consequently standing timber, with its relation to the Northwest, its present extent of production and consumption, and its hopes for the future.

A picture of the continental and in fact the world production and consumption is given, together with a glimpse of our population and rate of growth. There is also a short description of the different processes used. In the latter part of the paper a few of the points in a mill where waste occurs are enumerated,

and means for avoiding at least part of these wastes are suggested. [Paper No. WDI-50-3]

Lacquer and Varnish Films

By PAUL S. KENNEDY

Vice-President, Murphy Varnish Co., Newark, N. J.

THIS paper is a study revealing a definite similarity of failures, pointing out the problems calling for research work and discussing the development of a clear lacquer to withstand outside exposure on wood. The author in his treatment discusses respectively fracture failures of lacquer and varnish films; the basic similarity of lacquer and varnish; desirable qualities to incorporate in lacquer films; synthetic lacquer resistant to the ultraviolet rays of sunlight; and synthetic lacquer material for work subject to outdoor exposure. [Paper No. WDI-50-4]

Investigation of the Pulp and Paper Industry In the State of Washington

By BRUCE WALLACE ROSS and SEICHI KONZO

Department of Mechanical Engineering, University of Washington, Seattle, Wash.

IN THIS paper the authors discuss the pulp- and paper-manufacturing industry as it is conducted today and show that, owing to location, source of supply water supply for both power and process, labor, etc., the state of Washington presents many attractions to the prospective plant builder.

Of the subjects taken up, the first has to do with the materials used in the manufacture of paper. Then the several species of woods found in the United States, with particular emphasis on the state of Washington, are discussed, together with statistics concerning quantities available. One of the sources of supply mentioned is mill waste, and the possibilities of carrying on pulp operations in cooperation with saw-mill activities are discussed.

Pulp-making processes also are treated, those receiving attention being the mechanical process, the soda chemical process, the sulphate process, and the sulphite process.

The process of making paper is touched upon, but owing to the fact that complete treatises on this subject may be obtained without difficulty, little more than a brief review is given.

Interesting statistics on the consumption of wood pulp, its production in the United States, particularly in Washington, and its exportation appear in the paper. [Paper No. WDI-50-7]

Improvements in Handling Methods in the Woodworking Industry

By R. K. MERRILL and G. H. RODERICK

Respectively, Chief Mechanical Engineer, Assistant Engineer, American Seating Co., Grand Rapids, Mich.

THE authors deal with handling methods in that portion of the woodworking industry which starts with the purchase of boards and veneer from the mills, or what might be called the wood-dimensioning and fabrication industry. They take up respectively power-driven transfer cars, traveling cranes for serving kilns, monorail carriers for handling packaged lumber, electric lift trucks, elevators for inter-floor material handling, disposal of wood waste, and conclude by describing various applications of conveyor systems. [Paper No. WDI-50-5]

Static Loads upon Bus Bodies

By CHARLES B. NORRIS and JOSEPH A. POTCHEN

Respectively, Engineer and Member of Research Department, Haskelite Mfg. Co., Grand Rapids, Mich.

IN THIS paper the authors give a report of tests made to determine the static loads due to the interaction of a body and the chassis upon which it is mounted, and also a description of the methods employed. An appendix records the experimental data, and shows the methods of analysis and computation in detail. [Paper No. WDI-50-6]

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